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Psychological Monographs: General and Applied

Control of Behavior in Chimpanzees and Pigeons by Time Out from Positive Reinforcement[1, 2]

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THIS series of experiments is an analysis of some properties of behavioral control by stimuli which are aversive because positive reinforcement is discontinued. The basic paradigm used in these investigations for studying this kind of control uses a "time out" from positive reinforcement as the aversive event. To study the effect of the time out, a simple response, such as a pigeon's peck at a circular disk, or a chimpanzee's press of a toggle switch, was maintained when occasional pecks or presses were followed with food. Reinforcements became available on a variable schedule, which produced sustained responding at substantial rates. The resulting performance then served as a base line on which to assess the effects of the introduction of the aversive stimuli. To generate the aversive event, reinforcement was withheld in the presence of one stimulus but alternately continued in the presence of a second stimulus. When the rate of responding fell to zero in the presence of the stimulus where reinforcement was discontinued, that stimulus, called the time-out stimulus, could then be used as an aversive event and its effect on the base-line performance measured.

The "time out" is useful for interrupting an experiment, since all that is required is that a stimulus be changed. Hence, the time out has been used:

1. To begin and end experimental sessions (**6**). A time out at the beginning of the experiment enables effects of handling the animal to disappear before the experiment is started; a time out at the end of the experimental session terminates the daily session without the presence of the experimenter.

2. In drug experiments, by interrupting the experiment with a time out and continuing the experiment some time later when the drug has had its maximum effect (**3**).

3. As a way of analyzing and controlling the temporal properties of the animal's past behavior on a current performance (**7**). For example, the discriminative effects of the reinforcement can be minimized if it is followed by a time out, so that, when the experiment is resumed, a period of time has elapsed during which the reinforcement would have been effective.

A time out from positive reinforcement has been used to punish responses in the development of a discrimination, or differentiation. The aversive properties of a time out were also evident in experiments where a time out scheduled during a fixed-ratio performance disrupted the performance severely, because the high fixed-ratio rate of responding resulted in an inevitable correlation of the time out with a response (**7**).

Finally, Morse and Herrnstein, using pigeons, demonstrated that behavior could be maintained because it postponed a time out (**13**).

The primary aversive stimuli have relatively fixed effects. In contrast, the effect of the time out is determined by the schedule of reinforcement it interrupts. At extreme values of some schedules of reinforcement, the time out may become positively reinforcing instead of aversive.

[1] This study is part of a project supported by the United States Atomic Energy Commission under Contract AT-(40-1)-1553.

[2] The part of Experiment IV using pigeons was carried out in the Department of Pharmacology of the Harvard Medical School. Thanks are due to Otto Krayer and P. B. Dews for making the facilities available.

[3] Now at the Institute for Psychiatric Research, Indiana University Medical Center.

Morse and Herrnstein studied this property of the time out in the extreme case by experiments in which pigeons were reinforced on (*a*) large values of fixed-interval schedules, or (*b*) schedules in which low rates were differentially reinforced; that is, responses were reinforced only when they were spaced at least five minutes from a preceding response (**9**). They found that the stimuli associated with these schedules were aversive, since the pigeon had a strong disposition to peck a second key which interrupted the experiment for a long interval of time (e.g., three minutes).

Most of the punishments in human affairs involve the withdrawl of positive reinforcements (time out) rather than primary noxious events, or aversive stimuli. Jails, discharge from employment, and ostracization are a few of the more extreme forms. Even when corporal punishment is used, as for example in parental control of children, its effect is confounded with time out from positive reinforcement. A parent who spanks a child is less likely to provide the normal positive reinforcement.

Because the function of the time out depends (at least at extreme values) on the schedule of reinforcement from which it is derived, a single schedule of reinforcement and body weight was used in all of the experiments reported here. (An exception was made in the part of Exp. III using pigeons.) A variable-interval schedule with a mean of three minutes (VI3) was chosen as a moderate value. The average interval between reinforcements was three minutes, and the actual intervals were randomized between zero (successive responses) and six minutes. Such a variable-interval schedule will normally produce a moderate and near-constant rate of responding. Furthermore, the experimental session is long enough to impose repeated stimulus conditions, and also to minimize the relative importance of behaviors associated with too frequent eating. At the same time, the reinforcements occur frequently enough to prevent the schedule of reinforcement from becoming aversive.

Subjects

The subjects of the experiments were two adult chimpanzees, Yerkes Colony No. 67 (Jed) and No. 97 (Verb), 10 and 15 years old, respectively. The animals had a prior history in various manual discrimination experiments. In Exp. III, the subjects were two White Carneaux male pigeons, approximately two years old. They had a history of variable-interval reinforcement, during which their weights were varied.

Apparatus and Procedure

The principles used in the design of the apparatus were described elsewhere (**6**).

The chimpanzees' living quarters consisted of a room (12 by 12 feet) adjoining a fenced enclosure (15 by 15 feet). The apparatus was permanently mounted in the indoor portion (the experimental chamber). While one subject took part in the experiment, the second subject was locked out in the fenced enclosure. A scale permanently mounted from the ceiling of the experimental cage was used to weigh the animals before each experimental session. The animals were trained to hang quietly from the scale by successive approximation of the final behavior (**18**). Then, hanging from the scale was reinforced only when an appropriate light was on, so that the animals could be weighed at any time simply by turning on the light. The behavior recorded was the operation of a telephone-type key, 30 inches from the floor. The food magazine delivered alternate 50-calorie portions of hard whole wheat cracker and Purina monkey chow into a food tray 12 inches to the left of the key. Control and recording equipment were kept in an adjoining room.

Number 97 entered the experimental chamber at 9:30 A.M. and remained until 4:00 P.M.; No. 67 entered at 4:30 P.M. and remained until 8:00 A.M. The animals were kept in the same

room between 8:00 and 9:00 A.M., when both compartments were cleaned. The beginning and end of the experimental sessions were marked by the presentation and withdrawal of an overhead light. The daily session was terminated when the animal received 55 to 60 reinforcements, or when eight hours elapsed, whichever came first. The absence of the light controlled a near-zero rate of key pressing, because of differential reinforcement before the start of the experiment.

The animals were maintained at approximately 80% of their free-feeding body weight. They were fed a supplement of yeast tablets, two oranges, and four ounces of evaporated skim milk after the experimental session, when they went to the outside part of the living quarters. Any day when an animal's weight exceeded its designated experimental weight, the experimental session was postponed and the animal fed only supplementary rations. Extra food was given after the experimental session whenever the subject's weight fell below the designated experimental weight for several days.

The time out was programmed by shutting off the lights in the experimental room and disconnecting the reinforcing circuits. Any response occurring during the time out extended its full duration. The recorder paper feed did not run during the time out. Any responses occurring would be noted by a vertical rise in the recording pen. The rate of responding remained essentially zero during the time out. In all of the experiments the time out lasted 10 minutes except in the occasional instances where a response during the time out prolonged it. The intervals in the variable-interval schedule averaged three minutes and ranged from several seconds to six minutes in an arithmetic progression, except for a slightly lessened density of short intervals. The variable-interval schedule used with the pigeons in Exp. III averaged six minutes, varying from several seconds to 12 minutes.

The apparatus used with the pigeons in Exp. III is described elsewhere (6). No reinforcement could occur when a response produced a time out.

The actual order in which the experiments were carried out was I, II, IV, V, and III.

Experiment I. The Pre–Time-Out Stimulus

The suppression of behavior by a stimulus preceding an aversive event (pre-shock, pre–time-out, or pre-aversive stimulus) is an important case in a survey of the properties of an aversive stimulus. This is the experimental paradigm first demonstrated by Estes and Skinner (5) and later extensively used by Brady and Hunt (2). Herrnstein, extending the pre-aversive procedure to the time out, found that the pre–time-out stimulus suppressed behavior only when the reinforcement was given very frequently—e.g., a variable-interval schedule with a mean of 30 seconds. At higher mean values of the variable-interval schedule, however, the pre–time-out stimulus controlled a higher rate of responding than the prevailing interval rate. Herrnstein interpreted this increased rate as positive reinforcement by the time out because of the aversive properties of the schedule of positive reinforcement (8).

This experiment investigates the pre–time-out procedure in the chimpanzee at a moderate value of the variable-interval schedule, chosen to emphasize the aversive properties of the time out rather than the schedule of reinforcement.

Procedure

The subjects were reinforced on a variable-interval schedule for 65 hours following one session of continuous reinforcement. The 30-second, pre–time-out stimulus was a red lamp just above the key. The red light appeared at various intervals, averaging every 10 minutes. Reinforcements occurred on the three-minute, variable-interval schedule, independently of the red light. The red light was not followed by the time out for the first two sessions of the experiment. On the third session, the first response 30 seconds after the appearance of the red light produced a time out that interrupted the experiment for 10 minutes. During the remainder of the experiment, the effect of the red light on the rate of responding was measured variously with and without the time out following the red light. To check for artifacts, control sessions were carried out in which the red light was disconnected, but all of the recording circuits were still in effect.

Results

Figure 1 contains summary graphs of the whole experiment for both animals showing the ratio of the rate of respond-

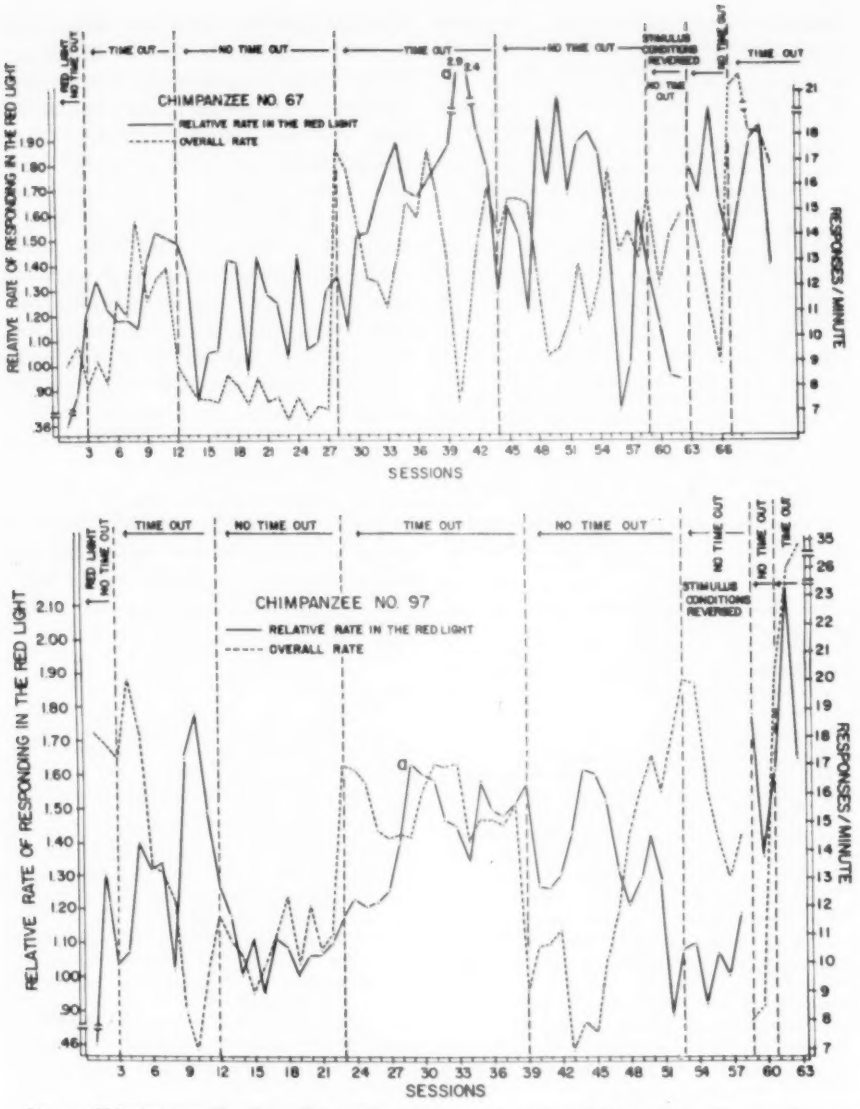

FIG. 1. Chimpanzees No. 67 and 97. The relative rate of responding during the pre–time-out stimulus and over-all rate of responding. Each point is the average of an entire daily session.

ing during the pre–time-out stimulus to the over-all rate. The time out increases the rate of responding in the presence of the pre–time-out stimulus, although the effect is not completely reversible. The highest relative pre–time-out rates of responding occurred when the over-all rate was low.

Rate of responding during the pre–time-out stimulus relative to the over-all rate of responding. Before the time out was introduced, the rate during the red light was low for both animals. After the time out was introduced, the rate of responding in the presence of the red light increased for both animals and remained considerably above the over-all rate. When the time out was discontinued in Session 12, the rate of responding during the red light fell for both animals. Number 97's rate quickly reached a value approximating the general level of responding. Number 67, however, showed many sessions in which the rate of responding during the red light increased to values as high as the previous procedure with the time out. When the time out again followed the red light, No. 67's pre–time-out rate increased markedly, reaching approximately 1.7 times the over-all rate; and on two sessions it reached 2.9 and 2.4 times the over-all rate. Number 97 also showed an increase over the pre–time-out rate of responding; but this increase was not so marked as that of No. 67. The rate during the red light reached approximately the same value as during the previous time-out procedure.

When the time out was discontinued for a second time, the rate of responding during the 30-second period of red light remained high. To control for possible artifacts, sessions were carried out in which the red light was disconnected, with the recording program remaining as before. Both animals showed rates of responding approximately equal to the over-all rate.

To investigate the continuing control of a high rate by the red light in the absence of the time out, the stimulus conditions were then reversed. The red light remained on for the bulk of the session, and the pre–time-out stimulus became a 30-second period in which the red light was off. The rate of responding during the 30-second intervals in which the red light was off fell relative to the over-all rate during the rest of the session when the red light was on. The rate fell to the value of the over-all rate, but not below it. When the original stimulus conditions were restored (the time out still not following the red light), the rate of responding again increased, reaching the level present before the reversal of the stimulus conditions. For No. 97, the rate during the red light then reached the highest rate of responding yet observed.

Over-all rate of responding. The over-all rate of responding, shown in the second curves of Fig. 1, shows a relation both to the introduction and removal of the time out and the relative rate of responding during the red light. The over-all rate of responding fell when the time out was discontinued (Sessions 12–27) and rose markedly when it was reintroduced (Session 28). The second removal of the time out had no obvious effect, but the reintroduction of the time out on Session 66 was accompanied by another marked rate increase. Number 97, in Fig. 1, showed a similar effect of the time out. The over-all rate increased on Session 23, when the time out was reintroduced, and fell on Session 39, when it was discontinued. The rate fell again on Session 59, with no time out, and increased on Session 61, with its reintroduction.

The highest relative pre–time-out rates of responding occurred when the over-all rate was low. For No. 67, on Sessions 33, 40, 50, and 65, peak values of the pre–time-out rate of responding occurred with the lowest values of the over-all rate of responding. Conversely, when the over-all rate reached its peak values, the relative rate during the red light tended

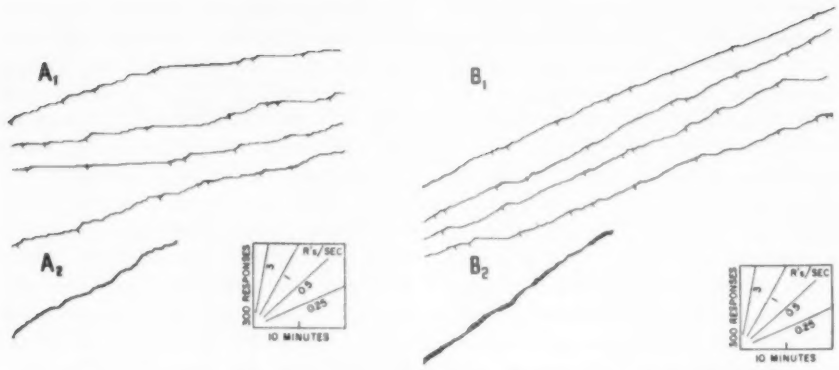

FIG. 2. Chimpanzees No. 67 and 97. Cumulative curves of an entire daily session showing the highest pre–time-out rates of responding relative to the over-all rate. Record B contains the performance during the pre–time-out stimulus only.

to fall. Note, for example, that the two curves cross frequently. Number 97 (Fig. 1) shows a similar performance. Peak values of the relative pre–time-out rate are associated with the lowest values of the over-all rate (Sessions 10, 44, and 60). However, there is no relation between high over-all rates and low values of the relative pre–time-out rate, as with No. 67.

Figure 2 contains the cumulative curves of an entire daily session, showing the performances for both animals, when the highest relative pre–time-out rates of responding were observed (at the points marked *a* in Fig. 1). In each case, Record 1 contains the entire performance, and Record 2 contains only the behavior during the pre–time-out stimulus. The diagonal marks indicate the start of the 30-second period during which the red light was on; reinforcements and the position of the time out are not marked on the curves. The grid in the lower right part of the figure gives the coordinates, the scale of the record, and several reference slopes in responses per second.

In Records A-1 and A-2, the 40th session for No. 67, the pre–time-out rate was 2.9 times as high as the over-all rate. The over-all rate of responding was low, with highest rates of the session occurring during the pre–time-out period. Occasional low rates appeared during the pre–time-out stimulus, as well as high rates elsewhere. The performance for No. 97 in Records B-1 and B-2 was similar, except for a higher over-all rate, showing more sustaining responding. The record contains the 29th session, where the pre–time-out rate was 1.6 times the over-all rate. Here, the rates of responding during the pre–time-out stimulus were frequently higher than any appearing elsewhere. Occasional instances occurred where the rate during the red light was lower than the prevailing rate.

When the pre–time-out rate was low relative to the over-all rate, the absolute values of the pre–time-out rates of responding were still substantial. In the main, the effect of the pre–time-out stimulus was to sustain responding rather than increase the local rate.

Discussion

The pre–time-out procedure produces an increase in rate of responding during

the pre–time-out stimulus, rather than a decrease, as with the preshock stimulus. In this experiment the increased rate during the pre–time-out stimulus cannot be interpreted as behavior reinforced by an aversive variable-interval schedule of reinforcement. Moderate schedule values were used; and, as Experiments III, IV, and V show, the interruption of the same schedule of reinforcement in the same animals is a highly aversive event.

Examination of the temporal relations of responses during the pre–time-out stimulus, the reinforcement, and the time out may suggest a basis for the increase in rate during the pre–time-out stimulus. The likelihood that a given response will produce a time out is high after a pause because the time out occurs at a fixed interval following the appearance of the red light. In the extreme case a response spaced 30 seconds from a previous response will always produce a time out. Conversely, only a small fraction of responses emitted at higher rates produces time outs. The result is a differential punishment of spaced responding because spaced responses are more likely to produce a time out. Also, the likelihood of a reinforcement following long pauses is low. Pauses of 30 seconds or more during the pre–time-out stimulus are never reinforced. This contingency is somewhat similar to schedules of reinforcement where the reinforcement is "set up" for a brief period of time (limited hold) rather than the normal procedure of the reinforcement being held indefinitely (**7**). The above contingencies produce large effects when programmed explicitly. Experiment V shows that the selective punishment of spaced responding is effective in controlling the rate of responding. Experiments with pigeons and rats have shown effective control of the rate of responding when reinforcement is withheld until a response occurs at the designated value (**16, 17, 19**).

The fact that the pre–time-out rate of responding generally did not exceed the highest prevailing rate elsewhere during the session also suggests that a major effect of the time out is to eliminate long pauses.

Both animals confirm the effect of the time out in increasing the over-all rate of responding (see Exp. II). Therefore, the effect of the time out might not be completely under the control of the red light, or the time out may have effects other than the contingencies in the red light described above. Because the time out following the red light produces sustained responding at the highest prevailing rate during the pre–time-out stimulus, its effect is more marked at lower over-all rates of responding. This confirms Herrnstein's finding that the relative rate during the pre–time-out stimulus increased when the frequency of reinforcement was deceased. The over-all rate of responding declined as reinforcements occurred less frequently.

The failure of the pre–time-out rate of responding to return to the level of the base-line rate after the time out no longer occurred indicates a large order of magnitude of control. There was no indication that the pre–time-out rate was falling during the 23 sessions in which the time out no longer followed the 30-second, red-light period. The apparent irreversibility of the process might be due at least partially to the fact that the discontinuance of the time out did not provide any new contingency opposed in effect to the time out.

As in Experiments III, IV, and V, No. 67 showed a greater sensitivity to the effects of the time out than did No. 97.

Experiment II. The Effect of a Periodic Time Out on the Over-All Rate of Responding on Variable-Interval Reinforcement

The effect of a time out in increasing the rate of responding on a variable-interval schedule was confirmed during the preliminary conditions of the avoidance experiment reported in Exp. IV. The avoidance procedure of Exp. IV produced a condition where the performance on the variable-interval schedule of food reinforcement was periodically interrupted by a time out, because no behavior had yet developed on the avoidance lever to postpone time outs. The periodic interruption of the experiment produced a marked increase in the over-all rate of responding. The avoidance experiment was then postponed so that the effect of the time out on the variable-interval rate might be examined in more detail.

Procedure

The performance on the variable-interval schedule was compared with and without time out. In the time-out procedure the subjects had access to the three-minute, variable-interval food reinforcement schedule for 60-second intervals, separated by three minutes when the time-out stimulus was present. The time-out procedure was compared with a control procedure of three-minute, variable-interval reinforcement without interruptions. In chimpanzee No. 67 the effects of time out and no time out were studied in alternate sessions for the first four sessions. The fifth and sixth sessions began without time out for the first hour, followed by the time-out procedure for the remainder of the session. In chimpanzee No. 97 the time out was studied in alternate sessions for the first two sessions. For the remaining four sessions of the experiment the procedure changed after the first hour of the session. In some cases the session began with time outs during the first hour, and in others with no time out. The previous history of the subjects is recorded in Exp. I.

Results

The rate of responding with the time-out procedure was always higher than without the time out. The ratio of rates of responding under time-out and no-time-out conditions ranged between 5.1 and 2.3 for No. 67 and 3.7 and 1.6 for No. 97.

Records A and B of Fig. 3, which contain the entire fourth and fifth sessions for No. 67, show a more detailed account of the effect of the time out. The recorder paper feed stops during the time out. Reinforcements are marked by the diagonal lines on the record. In Record A the session began with three-minute, variable-interval reinforcement, with time outs every minute. After one hour of variable-interval reinforcement (at the arrow), time outs were discontinued for the remainder of the session. The rate of responding fell within 10 minutes and showed a continuing decline through the remainder of the session. On the following day, shown in its entirety in Record B, the session began with variable-interval reinforcement, with no time outs. After an hour (at the arrow), the time-out procedure was reinstated for the remainder of the session. The rate of responding increased as soon as the time out was added. Pauses up to 30 seconds occur after many time outs. These pauses following time outs also occurred in Exp. III, and have been previously reported by Herrnstein in other experiments using variable-interval reinforcement and time outs with a pigeon (**8**).

Number 97, the animal with the higher over-all rate, showed the same effect of the time out. The first discontinuation of the time outs was immediately followed by a fall in rate. On the following day, when the time out was reintroduced after an hour, the rate of responding increased, interrupting the progressive decline in rate that is a usual characteristic of variable-interval per-

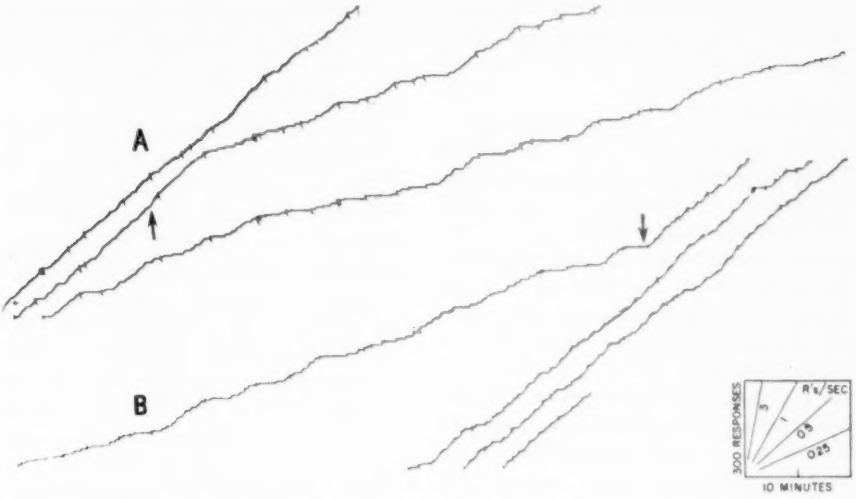

FIG. 3. Chimpanzee No. 67. Record A: The session is interrupted every minute. At the arrow the session is no longer interrupted. Record B: The following session. Beginning at the arrow, the session is interrupted every minute.

formances. The pauses following time outs were more marked for this animal than for No. 67.

The periodic time out has similar effects when the entire session is interrupted. Figure 4 contains two successive daily sessions for No. 97, comparing the performances with and without time out. Record A, without time out, shows a low over-all rate of responding with marked negative curvature during the session, reaching near zero by the end of the session. On the following day (Record B) the periodic interruption of the experiment increased the over-all rate by a factor of more than two. The increased over-all rate was caused by sustained responding rather than higher local rates of responding. Segments at *a*, *b*, *c*, and *d*, in Record A, for example, were emitted at the prevailing rate of Record B. Brief pauses follow most of the time

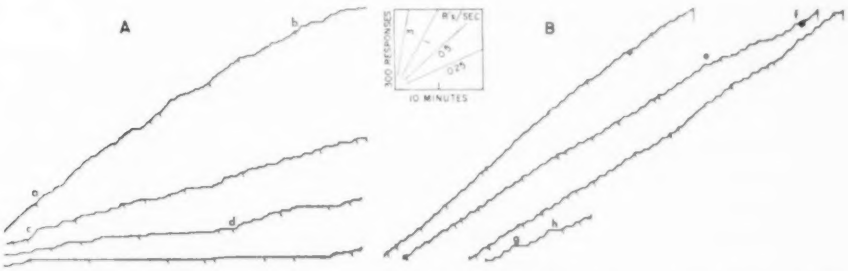

FIG. 4. Chimpanzee No. 97. Record A: A complete daily session without interruption. Record B: The session following Record A, where the session is interrupted every minute.

outs, as the wavy character of the record indicates. They are especially marked in the region *e* to *f* and at *g* and *h*.

Discussion

The increased rate of responding when the variable-interval reinforcement procedure was periodically interrupted confirms the effect of the time out on the rate of responding during the pre–time-out stimulus in Exp. I. The lesser amount of food per unit of time under the time-out conditions confounds the result somewhat; but the rate of food ingestion is probably not a large enough factor to produce the order of magnitude of rate changes reported here. Under the highest rate of food delivery, reinforcements are still spaced on an average of every three minutes. Contingencies are present in this experiment (similar to those already described in Exp. I) which could be responsible for the increased rate of responding when the session is interrupted periodically. The likelihood of a time out occurring is higher after longer pauses than shorter pauses. Hence, the class of reinforced responses will be partially restricted in the direction of responses spaced closely, because a higher proportion of distantly spaced responses will produce time outs (hence no reinforcement) than closely spaced responses. This lower frequency of reinforcement is tantamount to the reinforcement of higher rates. The contingency here is also similar to that of reinforcement schedules where the reinforcement is "set up" for a brief period rather than being available until the next response (limited-hold reinforcement). The reinforcement on a limited-hold basis reduces the likelihood of reinforcement after long pauses, just as in the time-out procedures of Exp. I and II, and increases the rate of responding.

Experiment III. The Suppression of Behavior by a Stimulus Preceding a Time Out from a Schedule of Positive Reinforcement

In this experiment the aversive properties of the time out were emphasized by terminating the pre–time-out stimulus, without a time out, if the rate of responding were low enough during its latter part. Pauses initiated during the pre–time-out stimulus reduce the likelihood of a time out and make a reinforcement more probable. Responses emitted at higher rates during the pre–time-out stimulus, however, are more likely to be punished. The contingencies are just opposite to those of Exp. I, where the first response 30 seconds after the appearance of the pre–time-out stimulus is followed by a time out. There, a pause initiated during the pre–time-out stimulus made punishment more likely. As a control procedure, the frequency of reinforcements on the variable-interval schedule was decreased to every six minutes, on the average, a value at which Herrnstein's experiment showed increased rates of responding during the pre–time-out stimulus. The experiment was first carried out with pigeons and then confirmed with the chimpanzees of Exp. I and II.

Pigeons

Procedure

The subjects of the experiment were two adult pigeons, maintained at approximately 80% of their free-feeding weight. Pecks at a translucent key were reinforced on a six-minute, arithmetic variable-interval schedule of reinforcement. The longest interval was 12 minutes and the shortest, several seconds. In order to maintain the low frequency of reinforcement without an excessively long programming tape, a few of the shorter intervals were omitted. The experiment began with a procedure similar to that of Exp. I. A blue light appeared behind the key every 11 minutes, and the first response 30 seconds after the appearance of the blue light (pre–time-out

stimulus) terminated the experiment for 10 minutes. The procedure was then changed so that the blue light went off without a time out if the rate of responding were low enough during the last part of the pre–time-out stimulus. This was done by arranging a short period of time in the last part of the pre–time-out stimulus (two to five seconds) when a peck would produce a time out. If no response occurred, the stimulus terminated without a time out. The level of deprivation, the length of the pre–time-out period, and the portion of the pre–time-out period during which a response would shut off the experiment were manipulated so as to minimize the number of time outs. This was done by increasing the bird's weight, reducing the length of the pre–time-out stimulus, and reducing the length of the period at the end of the pre–time-out stimulus until the rate of responding in the pre–time-out stimulus became zero. Then, the original values were restored: 80% body weight, and a 30-second pre–time-out stimulus, with responses during the last five seconds shutting off the experiment. When suppression of responding during the pre–time-out stimulus was complete, the original pre–time-out conditions were reinstated; that is, the first response 30 seconds after the appearance of the pre–time-out stimulus shut off the apparatus for 10 minutes.

The start of the pre–time-out stimulus is indicated on the records by the diagonal movement of the recording pen. Reinforcements are not indicated.

Results

The first peck 30 seconds after the appearance of the blue light produces a time out.

The results confirm the earlier experiment with chimpanzees (Exp. I) where the time out produced increased rates of responding during the pre–time-out stimulus.

First bird. Figure 5 shows the final performance for the first bird, after 51 hours of variable-interval reinforcement and 43 hours of reinforcement with the pre–time-out procedure. The figure contains a complete session except for two hours omitted between Records A and B and Records B and C. Without exception, the rate of responding is normal during the pre–time-out stimulus, even though long pauses and low rates of responding are common elsewhere, particularly after a time out, for example, at *e*. The magnitude of the pre–time-out rate of responding varies considerably. At *a* and *c* it is much below the prevailing rate. The average rate of responding is considerably higher during the blue light than elsewhere, because responding is always sustained during the pre–time-out stimulus, while pausing occurs frequently elsewhere.

Second bird. The second bird was only briefly exposed to the pre–time-out procedure (10 hours), and the responding during the pre–time-out stimulus was incompletely developed.

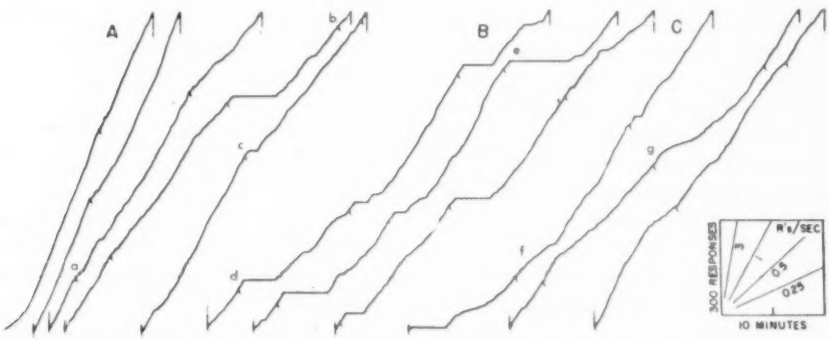

FIG. 5. First bird. The first peck 30 seconds after the appearance of the blue light produces a time out.

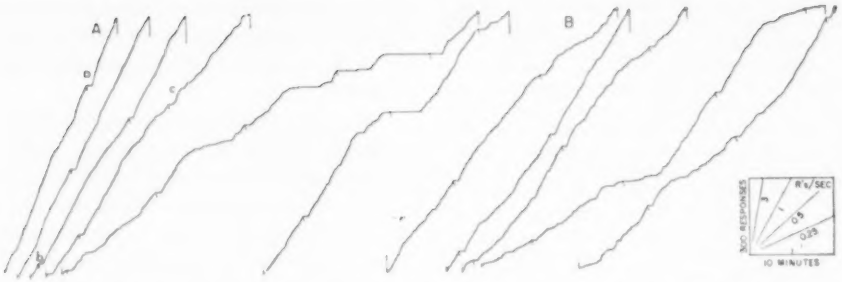

FIG. 6. First bird. Final performance showing suppression of responding during the blue light. Only responses during the final 5 seconds of the pre–time-out stimulus produce time outs.

Only responses during the latter part of the pre–time-out stimulus procedure produced a time out.

When the pre–time-out stimulus was allowed to terminate without a time out if the rate of responding were low enough, responding was almost completely suppressed during the pre–time-out stimulus.

First bird. Figure 6 shows the final performance on a 30-second pre–time-out stimulus, with standard food deprivation and responses during the last five seconds producing a time out. This performance was obtained after the following history: 14 hours in which the bird's weight was increased and the pre–time-out stimulus reduced to 15 seconds, with only responses during the latter 3 seconds producing time outs; 24 hours of an 18-second pre–time-out stimulus, with only responses during the last 5 seconds producing time outs. A period of 8 hours was omitted between Records A and B. In almost every case, suppression of responding was complete during the pre–time-out stimulus, as at *a*, *b*, and *c*. During the entire session, only 8 responses occurred during 78 presentations of the pre–time-out stimulus, and all of these occurred during the early part of the pre–time-out stimulus where they do not produce time outs.

Second bird. The second bird also showed complete suppression during the 30-second pre–time-out period. During 37 presentations of the blue light, only 9 responses occurred, but none during the period when they would produce a time out. In most cases, responding began immediately following the termination of the blue light, although the over-all rate of responding occasionally fell to zero with several successive presentations of the pre–time-out stimulus without any responding in between. The bird's history included 16 hours on this procedure in which it made no progress toward a suppression of responding during the pre–time-out stimulus. For 43 hours the weight of the bird was raised and the length of the pre–time-out stimulus then reduced to 12 seconds, with responses during the last 3 seconds producing a time out.

Return to the original pre–time-out procedure; the first response after 30 seconds produces a time out.

The return to the original time-out procedure again produced substantial rates of responding during the pre–time-out stimulus.

First bird. Record A of Fig. 7 is the start of the session following Fig. 6. Suppression was complete during the first

pre–time-out stimulus, at *a*. At the arrow, the procedure was changed so that the first response 30 seconds after the appearance of the blue light produced a time out. The blue light caused a zero rate, and no responses occurred during the remaining 16 hours of the session. The following session, Record B, began with the blue light on, and sporadic responding during the pre–time-out stimulus produced a time out after a pause of a few seconds. Records B and C show the remainder of the session, with 3 hours omitted in between. Responding was sustained during the pre–time-out stimulus with frequent instances of a rate higher than the prevailing rate, as at *c*, *d*, *e*, *g*, and *h*. The effect is somewhat more marked than that occurring during the final performance in Fig. 6. Pauses occasionally followed the time out, as in the segment at *f*, which also shows some compensation.

Second bird. The second bird's transition was similar. When the blue light remained on instead of terminating after 30 seconds, no responses occurred for almost 20 minutes, and the pre–time-out stimulus was turned off, ad libitum, without a response or a time out. Responding began soon thereafter, and the next two presentations of the pre–time-out stimulus showed complete suppression, with some intervening responding. The following session began with complete suppression during the pre–time-out stimulus; and following the third presentation of the pre–time-out stimulus, the procedure was changed so that the first response after 30 seconds produced a time out. The blue light remained on for 8 hours, when no responses occurred. The following session began with the pre–time-out stimulus in effect, and a single response during the blue-light stimulus produced a time out. Thereafter, the rate of responding during the pre–time-out stimulus increased, reaching values toward the end of the session which were roughly equal to the prevailing local rate. After further exposure to the pre–time-out procedure, responding was sustained during the pre–time-out stimulus, with frequent instances of high rates of responding. Rates of responding lower than the prevailing rate continued to occur, particularly toward the beginning of the session. The rate of responding

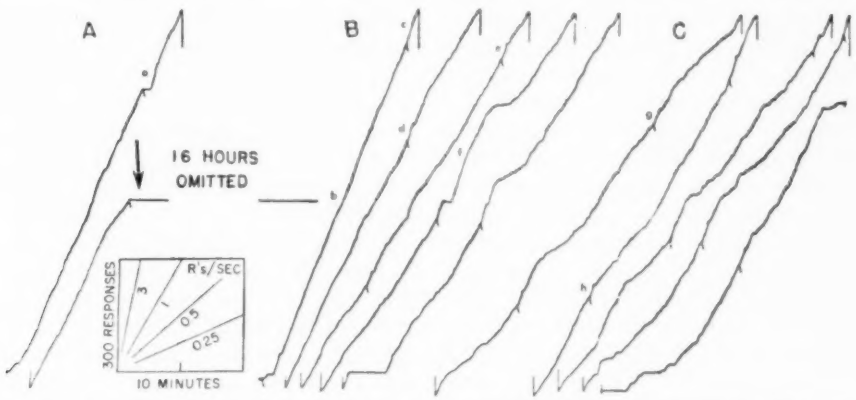

FIG. 7. First bird. Record A: Before the arrow, the blue light terminates if no pecks occur during the last 5 seconds. At the arrow, the first response 30 seconds after the appearance of the blue light interrupts the experiment. Records B and C: The session following Record A. The first response 30 seconds after the blue light produces a time out.

during the pre–time-out stimulus was approximately equal to the prevailing rate, and the performance was approximately the same as that which occurred earlier under the same procedure.

Chimpanzees

Procedure

The procedure reported for pigeons was carried out with chimpanzees No. 67 and 97. At the start of the experiment, the over-all rate of responding was low because of punishment of fast responses in a previous experiment. The pre–time-out stimulus (red light) was then presented every eight minutes. The first response 30 seconds after the appearance of the red light produced a time out. After 12 sessions for No. 97, and 9 sessions for No. 67, the rate of responding during the red light was approximately equal to the over-all rate. The procedure was then changed to emphasize the aversive properties of the time out by allowing the red light to terminate without a time out if the rate of responding were low during its latter portion. As with the pigeons, the length of the pre–time-out stimulus and the portion of the stimulus in which a response would produce a time out were varied so as to minimize the number of time outs. When the rate of responding during the red light became low enough so that nearly all of the pre–time-out stimuli terminated without a time out, the original values were reinstated.

Results

Suppression of lever pressing during the pre–time-out stimulus. Number 97 showed suppression during the pre–time-out stimulus after the following history: six sessions of a 20-second, pre–time-out stimulus with responses during the last five seconds producing time outs; three sessions where responses produced time outs during the last two seconds; and two sessions where responses produced time outs during the last five seconds. The length of the pre–time-out stimulus was then increased to 30 seconds, and Record A of Fig. 8 contains the entire second session. The over-all rate of responding was still lower than in Exp. I, II, and IV, probably because high rates

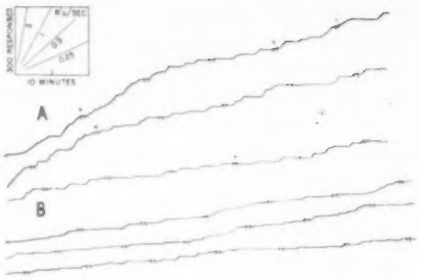

FIG. 8. Record A: Chimpanzee No. 97. Final performance. Responses during the final 5 seconds of the 30-second red light produce a time out. The oblique marks indicate the extent of the pre–time-out stimulus. Record B: Chimpanzee No. 67.

of responding were punished in a previous procedure. Suppression of lever pressing during the red light was virtually complete, with only one time out occurring (at *c*) and only 19 pre–time-out responses through the entire session. A few responses appeared in the middle of the interval, at *b*, and at the start of the interval, at *d*. The pre–time-out stimulus occasionally interrupted a substantial rate of responding, as at *a*; but the low over-all rate provided many instances where the pre–time-out stimulus occurred when the rate of responding was zero, as at *e*.

As in Exp. I, II, and IV, No. 67 showed greater sensitivity to the effects of the time out. By the second session of a 20-second pre–time-out stimulus, with responses in the final five seconds producing a time out, suppression of lever pressing in the presence of the red light was complete. No time outs occurred during the entire session, and only two responses occurred during the pre–time-out stimulus. Record B of Fig. 8 contains an entire session, showing suppression during a 30-second pre–time-out stimulus after a history the same as that of No. 97. The

over-all rate of responding was low, as with No. 97, probably because of the previous history of punishment of fast responding.

The first response after the 30-second red light produces a time out. Even after prolonged exposure, this procedure did not produce as sustained a rate of responding during the pre–time-out stimulus as during the previous performance on the same program.

The transition was very similar to that after the same procedures in the pigeon experiment, although not so extreme. Long pauses appear in the pre–time-out stimulus and elsewhere, with a corresponding decline in the over-all rate. When responding occurred, however, it occurred at normal rates of responding. No. 67, the animal with the low rate and greater reactivity to all of the previous time-out procedures, again exhibited a larger effect of the change in procedure. The over-all rate of responding fell to near zero for the last three hours of the session. Only 36 of the possible 58 reinforcements were delivered. The procedure was continued for 22 sessions, during which both the over-all rate and the rate during the pre–time-out stimulus rose; but the pre–time-out rates of responding still did not exceed the prevailing rates of responding. Figures 9 and 10 show the final performances. The over-all rates of responding remained high for both animals, and the frequency of negatively accelerated rate changes during the red light increased, as, for example, at *a*, *b*, *c*, *d*, *e*, *f*, and *g* in Fig. 9 and *a*, *b*, *c*, *d*, and *e* in Fig. 10. Occasionally, No. 67's rate of responding during the red light was near zero, as at *f* and *g*. Figure 11 shows the performances for both animals during the red light with less reduction. The segments of the curve in the vicinity of the pre–time-out stimulus are excerpted and arranged in order of occurrence, in Record A for No. 67 and Record B for No. 97.

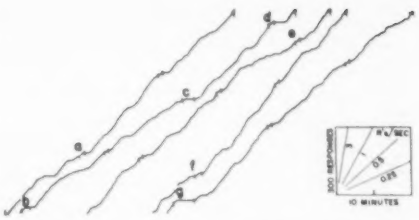

FIG. 9. Chimpanzee No. 97. The first response after 30 seconds in the red light produces a time out. Twenty-two sessions after the suppression during the previous procedure.

Only responses during the last five seconds of the red light produce a time out.

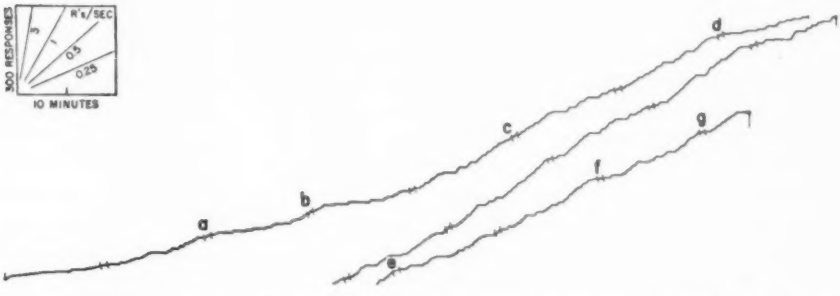

FIG. 10. Chimpanzee No. 67. The first response after 30 seconds in the red light produces a time out. Twenty sessions after the suppression during the previous procedure.

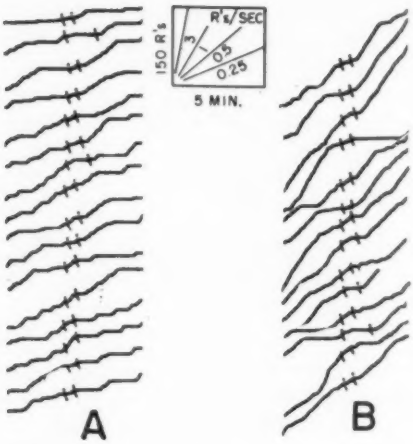

FIG. 11. Excerpts showing the performance during the red light with less reduction. Record A: Chimpanzee No. 67. Record B: Chimpanzee No. 97.

Neither No. 67 nor No. 97 progressed further toward sustained responding during the pre–time-out stimulus than the performance already described in Fig. 9 and 10. The procedure was therefore changed to find out the extent to which the earlier performance could be recovered when the pre–time-out stimulus could terminate without a time out if the rate of responding were low enough. The pre–time-out stimulus was reduced to 15 seconds, with only responses during the last 2 seconds producing time outs. After three sessions, the rate of responding during the red light became low enough so that no time outs occurred, and that portion of the pre–time-out stimulus was increased in which a response would produce a time out.

Number 67 again showed greater sensitivity to the effects of the time out. Suppression during the pre–time-out stimulus was virtually complete by three sessions, with only 34 responses occurring during the 18 presentations of the pre–time-out stimulus. The bulk of these occurred during one pre–time-out period. The performance for No. 97 is shown in Fig. 12, where segments have been excerpted in the vicinity of the pre–time-out stimulus and arranged vertically in order of occurrence. In spite of the large amount of responding during the pre–time-out stimulus (972 responses), only one time out occurs, because most of the responding is concentrated during the early part. Marked negative acceleration occurs in all of the pre–time-out periods except the 3rd, 4th, 5th, and 11th.

Discussion

Both the pigeon and chimpanzee experiments demonstrate that the time out is an aversive event which can suppress behavior during a pre–time-out stimulus. In the pigeon experiments, it was possi-

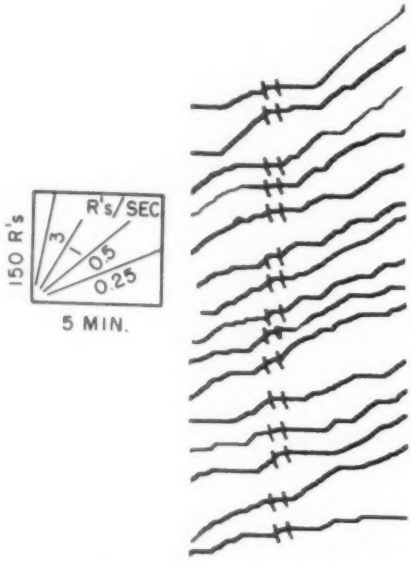

FIG. 12. Chimpanzee No. 67. Return to the procedure where only responses during the last 5 seconds of the pre–time-out stimulus produce a time out. Segments in the vicinity of the pre–time-out stimulus have been excerpted.

ble, in the same birds, to alternate between procedures which produced suppression or sustained responding at rates higher than the over-all rate. In the chimpanzee experiment, the same animals which showed sustained responding at rates higher than the over-all rate during the pre–time-out stimulus showed complete suppression when the pre–time-out stimulus could terminate without a time out. The subsequent return to the first procedure, however, did not increase the pre–time-out rates of responding to the earlier values (presumably as a function of the intervening exposure to the procedure emphasizing the aversive aspect of the time out). The increased rate during the pre–time-out stimulus is due to its effect on the rate of responding at the moment of reinforcement and the consequent differential reinforcement of high rates.

The suppression during the pre–time-out stimulus demonstrates a process in the control by a time out, which is similar to the suppression obtained with electric shock. The time out appears to have slightly different properties than the electric shock in that it has more specific action; that is, it limits the suppression to the pre–time-out stimulus. The preshock procedure often produces suppression elsewhere than during the preaversive stimulus, for example (1, 7).

The pre–time-out stimulus showed a high order of control over the pigeons' behavior, with suppression during 8 and 16 hours, respectively, for the two animals of the experiment. This order of stimulus control occurs in experiments with electric shock only at high intensities of the shock. Following the experiment producing suppression in the pre–time-out stimulus, both chimpanzees showed many instances of negatively accelerated rate changes in the pre–time-out stimulus under the procedure that previously produced sustained responding. The suppressive effect of the time out during the final part of the pre–time-out stimulus probably represents the concurrent operation of the two properties of the time out; the sustained responding early in the pre–time-out stimulus is due to the differential reinforcement of high rates by the time out, while the lower rate toward the end of the pre–time-out stimulus represents a temporal discrimination of the aversive effects of the time out. When only responses during the latter part of the pre–time-out stimulus produced time outs, the temporal discrimination became more pronounced and the complete suppression that developed during the first exposure to this procedure did not appear. This is similar to the result obtained by Azrin, who generated near-normal rates of responding during the first part of a preshock stimulus.

The pigeons showed no indication that a temporal discrimination was developing, but they were not exposed to the procedure as long as the chimpanzees.

Experiment IV. Avoidance Behavior

Another property of an aversive stimulus is its ability to maintain behavior which removes or postpones it. Sidman has extensively studied the avoidance of electric shock, with procedures in which a free operant is maintained because it postpones a shock. Morse and Herrnstein (13) extended the technique to the avoidance of a time out in the pigeon; and in the present experiment, this technique is used with the chimpanzee. The demonstration of the aversive properties of the time out is relevant to the interpretation of the results of Exp. I and III, where findings were analyzed by reference to two separate functions of the

time out. The animals, the schedule of food reinforcement, and the level of deprivation remain the same. Hence, the aversive properties of the time out derived from the present experiment are germane to the interpretation of the functions of the time out in those experiments.

Procedure

The experimental session began with the variable-interval schedule in force. Two keys separated by approximately 12 inches were present simultaneously. Responses on the right key (food key) were reinforced on the three-minute, variable-interval schedule used in the previous experiment. If no responses occurred on the left key (avoidance key), a three-minute time out occurred after every 45 seconds of experimental time. Each time the avoidance key was pressed it postponed the interruption of the experiment for a given period of time (RS interval). If the avoidance key was pressed frequently enough, the variable-interval schedule remained in force continuously. Four values of the RS interval were studied: 10, 5, 2, and 1 minutes. Figure 13 shows the actual sequence and the number of sessions in each value for both animals.

Since the food reinforcement was programmed by time, a sequence of responses on the avoidance key would increase the probability that the next response on the food key would be reinforced. Thus, the rate of avoidance responding would be spuriously inflated (12, 17.) Such accidental reinforcement was observed when the rate of No. 97's avoidance responding failed to fall following the increase of RS interval from 2 to 10 minutes. To prevent this spurious reinforcement, the timer programming the food-reinforcement schedule stopped for seven seconds every time an avoidance response occurred. This was done with both animals. This procedure increased the mean of the variable-interval schedule somewhat; but it ensured that the level of avoidance responding would not be inflated by reinforcement because of a spurious chain of responses.

The avoidance experiment began following the procedures already described in Exp. I and II. No responses occurred on the avoidance key for several sessions, however; and, because some responding was necessary before the avoidance contingency would have any effect, the food key was withdrawn for 30 minutes during which avoidance-key responses were reinforced by food on the variable-interval schedule. The food key was then replaced and the avoidance procedure reinstated.

Responding on the food and avoidance keys was recorded on separate cumulative recorders running concurrently. The displacement of the recording pen diagonally from the curve marked the occurrence of food reinforcement on the variable-interval curve and time outs on the avoidance curve. The recorder stopped during the time out, and the location of the time outs on the variable-interval curve is indicated by the small filled circles shown above the curve in Fig. 16. Figures of the avoidance behavior contain entire daily sessions.

Results

The results of the entire experiment are summarized in Fig. 13, which gives daily rates of responding for each session on the food and avoidance keys, as well as the frequency of occurrence of time outs. All of the sessions of the experiment are included, and each point is the average rate for the daily session. In general, the rate of avoidance responding increased when the interval by which each response postpones the time out was decreased, and vice versa. On all values of the avoidance schedule, rates of responding were considerably higher than the minimum amount of behavior necessary to postpone all of the time outs. Responding tended to occur in bursts at sustained rates rather than in single responses emitted at approximately the rate corresponding to the avoidance interval.

Chimpanzee No. 67. Figure 14 gives the early development of the avoidance behavior. Record A, the sixth session in which each avoidance response postponed the time out for 10 minutes, shows a very low rate of responding—one which is just sufficient to keep the schedule of food reinforcement in force continuously during most of the session. Seventy responses are emitted during the session, in bursts of 2 to 10. Record B contains the performance in the procedure where avoidance responses postponed the time out for 5 minutes (RS 5). It shows a

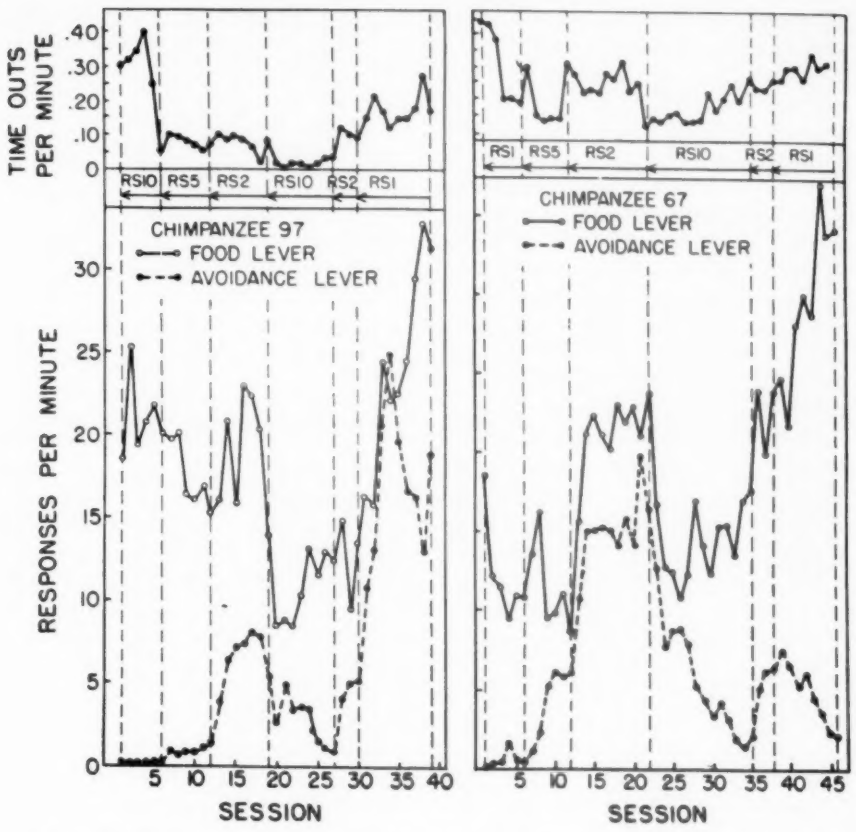

FIG. 13. Chimpanzees No. 67 and 97. Daily rates of responding on the food and avoidance keys.

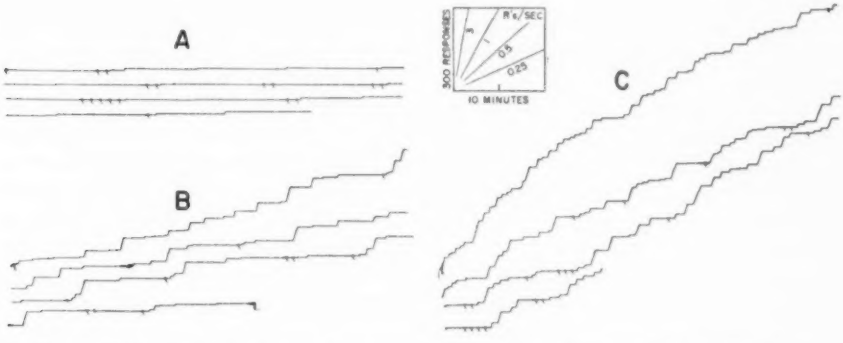

FIG. 14. Chimpanzee No. 67. Early development of the avoidance behavior—Record A: RS 10. Record B: RS 5. Record C: RS 2.

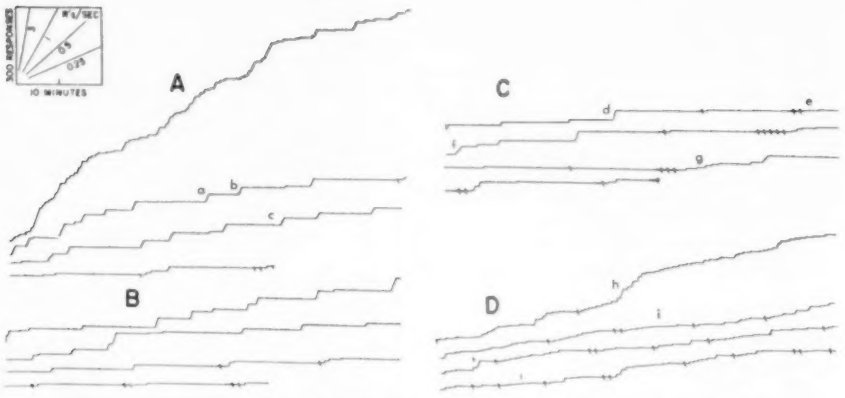

FIG. 15. Chimpanzee No. 67. Transition to RS 10 and subsequent return to RS 2.

higher over-all rate than that under RS 10 and a progressive decline in rate through the session. Intermediate rates of responding are absent, with most of the avoidance responses occurring in groups of 20 to 60, emitted at 2 responses per second. Record C contains the avoidance performance after 9 sessions on RS 2. The over-all rate increases over twice that of the previous procedure, but a larger number of time outs occur, particularly toward the end of the session, because of the progressive decline in the over-all rate. Avoidance responding is absent for periods up to 5 minutes, during which three to four time outs occur in a row. Intermediate rates of responding are still absent, although the size of the bursts is decreasing.

Figure 15 shows the transition of the avoidance behavior to RS 10 and the subsequent return to RS 2. Record A, containing the session following Fig. 14C, shows the re-exposure to the longer RS interval. The session begins with the high rate of avoidance responding from the previous shorter RS interval; but the rate of responding falls progressively, reaching a low over-all rate of responding consisting of long pauses separated by bursts of approximately 25 responses, as at *a*, *b*, and *c*. Eight sessions later, shown in Record B, the rate of avoidance responding remains substantially higher than in the final performance previously recorded in Fig. 14C. This level had been reached after the fourth session on RS 10. Because the rate of avoidance responding might be spuriously inflated as a result of accidental reinforcement, the procedure was then changed so that the tape scheduling the variable-interval reinforcement stopped for seven seconds each time an avoidance response occurred. Thus, responses on the avoidance key no longer increased the likelihood that subsequent responding on the variable-interval key would produce a reinforcement. Record C shows the performance four sessions after the initiation of the control procedure. The rate of responding falls to a level only slightly above the previous final performance on RS 10. Some sustained bursts of responding are still occurring, as at *d*, but intermediate rates of responding have become much more frequent, as at *e*, *f*, and *g*. The number of time outs is now com-

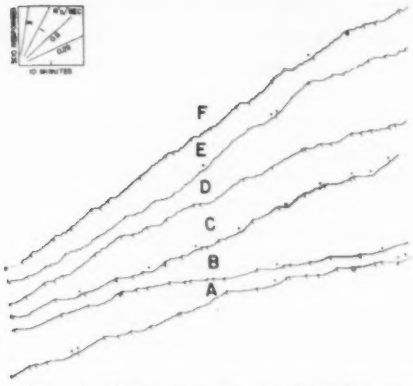

FIG. 16. Chimpanzee No. 67. Food-key performances corresponding to the avoidance behavior of Fig. 14 and 15.

parable with that recorded under the previous RS 10 procedure. The RS interval was then reduced to two minutes; Record D shows the performance after three sessions on this value. The rate of responding has increased considerably over the performance recorded previously under RS 10 in Record C; but it is much less than the performance recorded earlier under RS 2 in Fig. 14. This is largely a result of the disappearance of the sustained bursts of responding at high rates. Instead, the performance has given way to a finer grain in which many responses are occurring singly, or in groups of two or three, as at *j* and *l*. Instances still occur, however, where avoidance responding is sustained at high rates for large numbers of responses, as at *h* and *k*.

The corresponding performances on the food key are shown in Fig. 16, which gives the first hour of the session. The order of presentation of the segments has been inverted for more compact presentation. Records A and B are the food-key performances, comparable with Fig. 14 and 15 on RS 10. Record C shows the increase in the variable-interval rate of responding on the first session the RS interval was increased to two minutes. Records D and E contain the 8th and 12th sessions on the second exposure to the RS 10, and Record F shows the subsequent increase in rate of responding on re-exposure to RS 2 in the final session.

When the RS interval was decreased to one minute, the rate of responding began to decline continuously, finally reaching a value intermediate between the lowest RS 10 value and the performance under RS 5. Figure 17 shows the second through

FIG. 17. Chimpanzee No. 67. Seven consecutive sessions showing the development of a temporal discrimination in the avoidance responding.

the eighth sessions in reduced form. The over-all rate of responding declines continuously, because of the progressive disappearance of bursts of responding at high rates. By Record G, responding is sustained at a low constant rate, just sufficient to postpone most of the time outs. The frequency of time outs is higher toward the end of the session.

Figure 18 shows the final performance in greater detail. The avoidance behavior in Record B occurs at a low constant rate of responding, just sufficient to postpone most of the time outs. A brief burst of responding at a high rate occurs at *a*. The variable-interval performance on the food key, Record A, shows the increase in the over-all variable-interval rate. The small arrows over the curve indicate the exact locations of the time outs. Most of the time outs occur while the variable-interval performance is sustained, except for the group of eight time outs toward the end of the sessions, which occur during a pause. Nearly all of the time outs are followed by a brief pause in the variable-interval performance.

Throughout the experiment the over-all rate of responding on the food key went up whenever the number of time outs increased and decreased whenever the number of time outs fell. This relation confirms the findings of Exp. I and II on the effect of an ad libitum time out on a variable-interval performance.

Chimpanzee No. 97. The second animal in the experiment did not show so strong a disposition to emit large bursts of responding on the avoidance key during the early parts of the experiment. However, the avoidance rates of responding increased markedly under RS 1 toward the end of the experiment. Some evidence existed that temporal discrimination had started to form under RS 1, as with No. 67, but the experiment was discontinued too soon to show its development.

As in the previous experiments, No. 97 was less sensitive to the aversive effects of the time out.

Discussion

The present experiment confirms Morse and Herrnstein's result with the pigeon and shows that the postponement of a 10-minute time out from a variable-interval schedule of food reinforcement will maintain a substantial amount of behavior in a chimpanzee. The results also extend the generality of the aversive properties of the time out from this schedule of reinforcement, and support the interpretation of the results of Exp. II.

The avoidance behavior based on time out from positive reinforcement has some of the properties of avoidance of electric shock studied extensively by Sid-

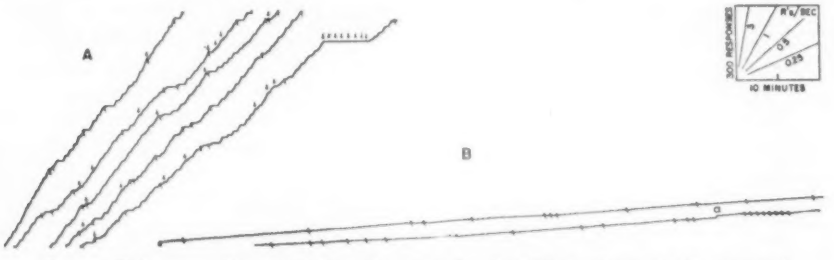

FIG. 18. Chimpanzee No. 67. Final performance showing full development of a temporal discrimination.

man. Over most of the range studied in this experiment the rate of avoidance responding varied inversely with the RS interval (15). With prolonged exposure to the avoidance contingency, avoidance rates tended to be progressively lower because of the development of a temporal discrimination. The initial rate of development of the avoidance behavior was similar to the results with electric shock in the rat, cat, and monkey, although the 10-minute RS interval in the present experiment was considerably larger than the values customarily used.

The high chimpanzee avoidance rate was characterized by bursts of responses separated by pauses, rather than the steadier intermediate rates of responding of the rat, cat, and monkey. Immediately following a time out, the rate of responding of the chimpanzee is uniformly low. With the rat, cat, and monkey experiments, however, shocks tend to be followed by a burst of avoidance responding. Because species properties are confounded in the relevant experiments, it is impossible to say yet what properties of avoidance behavior based on a noxious stimulus are different from those of avoidance behavior based on time out from a schedule of positive reinforcement. The large amount of uniformity in the properties of electric-shock avoidance over a wide range of vertebrates suggests that the important condition is the use of the time out rather than the species difference. Avoidance of time out from positive reinforcement has not been studied in other species extensively enough so that the role of the species in this behavior can be assessed. Experiments on the pigeon in which the time out was used as a punishment (see Exp. V) suggest that the pigeon is less sensitive to this contingency than the chimpanzee.

The progressive increase in the rate of responding on the food key during the last exposure to RS 10, 2, and 1 minutes occurs independently of changes in the avoidance rate. The magnitude of the increase of the food-key rates is greater than the change in the avoidance rates, and cannot be due to a simple shift of responses from the avoidance key to the food key. Nor is the increased food rate due to the periodically recurring time outs, which can of themselves produce a marked increase in rate. Earlier in the experiment, equal frequencies of time outs resulted in a much lower food-key rate. The increase in the food-key rate is probably related to the development of the avoidance behavior, and may be related to the temporal discrimination which developed concurrently on the avoidance key.

Avoidance of a time out from a schedule of reinforcement raises some questions about the basis of avoidance behavior. Most writers discussing avoidance of electric shock interpret the performance in terms of Pavlovian conditioning, based on reflexes elicited by the shock. Some feel that the reduction in these reflexes strengthens the avoidance behavior (10, 11). Others emphasize the punishment of all behaviors other than the avoidance response with the consequent development of these behaviors as conditioned stimuli for the reflex effects of the shock (4, 14, 15). Even though a time out from a schedule of positive reinforcement undoubtedly has some emotional effects, these probably are not of the magnitude caused by a high-voltage electric shock. Yet, avoidance behavior can still be maintained at a level comparable with that developed using shock. This suggests that an aversive stimulus may control behavior independently of its emotional, autonomic, or reflex effect.

Experiment V. Time Out from a Schedule of Positive Reinforcement as a Punishment

This experiment, using the same chimpanzees as Exp. I–IV, investigates the properties of a time out used as a punishment. A time out followed "fast responding" and reduced the rate of responding on a variable-interval schedule of reinforcement. Because the variable-interval schedule and the level of deprivation were the same as in the previous experiments, the results of this experiment, as well as the results of the earlier experiments in the paper, can be used to describe the general properties of this time out.

The variable-interval schedule was used as a paradigm for studying punishment because the constant rate of responding that emerges is not easily disrupted by the time out independently of its aversive effects, as it is in other interval schedules. Although a fixed-interval schedule, for example, has the advantages of the sensitivity and reproducibility of rate changes, the interruption of the experiment per se would disrupt the fixed-interval performance. Also, an interval schedule was used rather than a ratio schedule because of its moderate over-all rate of responding and frequent local rate changes. In a fixed-ratio schedule, with its sustained responding at a single high rate, the punishment would have little differential effect, since very few responses would go unpunished. Moreover, the schedule factors in the ratio schedule differentially reinforce high rates of responding, which oppose the effects of the punishment (7). The punishment of responses maintained on a fixed-ratio schedule is analogous to the differential reinforcement of low rates on a fixed-ratio schedule.

Only occasional instances of responses that qualified for punishment were actually punished. Therefore, the frequency of occurrence of the punished class of responses would be minimally constrained and could vary continuously over a wide range.

In the paradigm chosen here to study punishment, all responses are reinforced, and the punishment is used to reduce the frequency of occurrence of a selected class of responses. Another paradigm is possible in which a time out is used to eliminate behaviors which are occurring by induction, as, for example, in an extinction component of a multiple schedule, or in the differentiation of the topography of some behavior. These are important cases, but the rate of responding under the variable-interval schedule seemed to be a better case to study first because it permits a return to a base-line condition.

For convenience, I shall adopt the convention of designating the time between a given response and the preceding response as an interresponse time (IRT) and refer to the punishment of interresponse times even though the correct statement would be the punishment of a response having an interresponse time of a given value.

Procedure

The experiment was carried out following the procedures described in Exp. I through IV. Under the punishment procedure, lever presses spaced less than a given interval from a preceding response were followed by a time out. Every such instance, however, was not punished. The punishment occurred on a variable-interval schedule with a mean of 4.6 minutes and a range of 9 minutes. When the variable-interval punishment schedule designated a punishment, the first instance thereafter of a response qualifying for punishment was followed by a time out.

Recording

Both cumulative records and interresponse

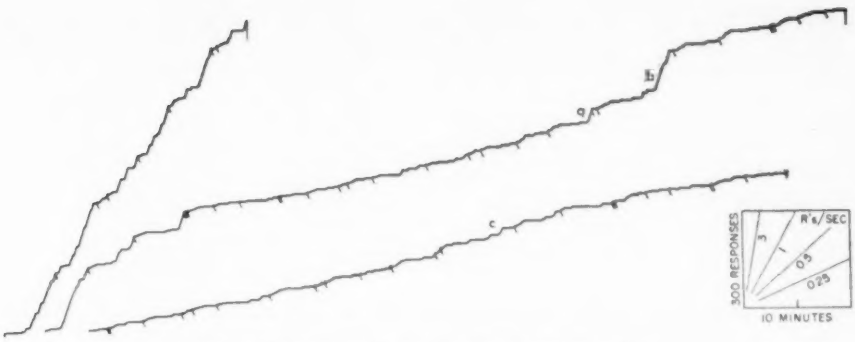

FIG. 19. Chimpanzee No. 97. Final performance on VI 3.

times were recorded. Reinforcements are indicated by the small marks diagonal to the record, and the points of occurrence of a time out are indicated either by the small dot or arrow over the record. The scale of the record changes from figure to figure; but both the ordinate and abscissa were compressed equally, so that the slopes of the curves are comparable. The interresponse-time recorder classified all responses occurring during the session into those between zero and 0.33 second from a previous response; 0.33 to 0.66; 0.66 to 1 second; 1 to 1.33; 1.33 to 1.66; 1.66 to 2 seconds; and thence by steps of 2 seconds until 22 seconds. Because this proved to be too fine a grain, not all of these compartments were used in the final analysis. The error of the interresponse-time recorder was less than 5%.

Plan of the experiment

A variable-interval base line was first established. Responses occurring within 0.75 second from a previous response were punished as specified by the variable-interval schedule designated above. This 0.75-second interresponse time proved to be too high a value for one animal, whose rate of responding was so high that nearly all of its responses fell within the punished category. The contingency was then shifted to the punishment of responses spaced 0.33 second or less. Performances were then recorded as the over-all rate of responding was progressively lowered by punishing responses spaced 1, 2, and 4 seconds. The time out was then removed, the variable-interval base line without punishment recovered, and the punishment procedure reinstated with responses occurring within 4 seconds of a previous response being punished. The experiment was discontinued for five weeks during the variable-interval reinforcement before the reintroduction of the punishment.

Results

Transition from No Punishment to Punishment of Responses Spaced Less Than 0.33 Second

Number 97. Figure 19 contains a final performance for chimpanzee No. 97 on the variable-interval schedule. The over-all rate of responding is high during the first 30 minutes of the session but then falls rapidly, from 0.75 response per second to less than 0.2 response per second. Local rates of responding continue to be high even toward the end of the session, as at *a*, *b*, and *c*, for example. Although this markedly negative curvature is a reproducible feature at this stage of development, it is an atypical variable-interval performance and probably a function of the previous exposure to the contingencies of Exp. I, II, and IV. On the following session, responses spaced 0.75

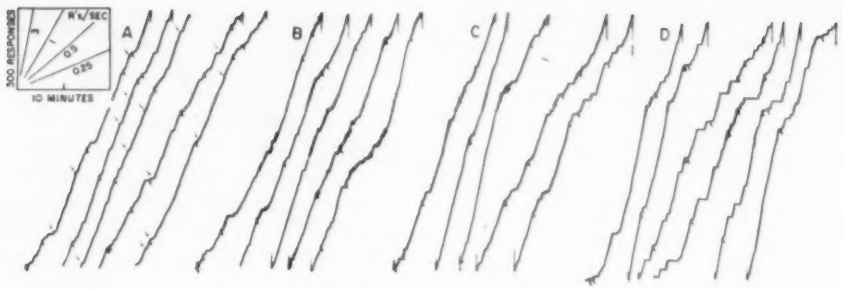

FIG. 20. Chimpanzee No. 97. The first hour of the first four sessions on the punishment procedure.

second were punished. The initial effect of the punishment is shown in Fig. 20, containing approximately the first hour of the first four sessions. In Record A the over-all rate increases from 1 to 1.5 responses per second. This performance is maintained throughout the entire session, during which 8,000 responses occurred.

Few responses are spaced *more* than 0.33 second, and the maximum number of time outs (indicated by the arrows in Record A only) occur. In the next session (Record B), 10,000 responses occurred with local rates of responding slightly less than 3 responses per second, so that nearly all of the responses in the session qualify for punishment. Beginning with the third session (Record C), responses spaced less than 0.33 second are punished. The rate of responding increases even further, reaching 10,300 responses in the third session and 12,700 responses in the fourth session (Record D), with local rates of responding reaching just under 4 responses per second.

Figure 21 contains the entire record of the third to eighth sessions in reduced form. In Record A, the rate of responding begins at the previous prevailing rate, but soon falls off to an intermediate value somewhat less than that occurring at the start of the session during the previous variable-interval reinforcement without punishment. Despite the marked fall in the over-all rate of responding, however, the frequency of responses spaced less than 0.33 second is high enough so that the maximum number of time outs is still being received. Records B through F contain the fourth through eighth sessions, during which the over-all rate of responding falls, the negative

FIG. 21. Chimpanzee No. 97. Responses spaced less than 0.33 second are punished. Third to eighth sessions.

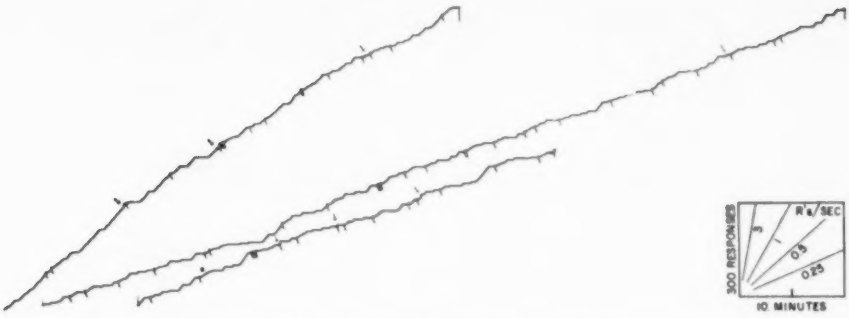

FIG. 22. Chimpanzee No. 97. Complete daily session showing the final performance with punishment of responses spaced less than 0.33 second.

curvature diminishes, and the number of time outs occurring reaches a low value.

The final performance is shown in Fig. 22, where the figure is reduced less. The number of responses emitted during the session is still the same as the number emitted before the punishment procedure (Fig. 19), even though responses spaced 0.33 second from preceding responses have been virtually eliminated (see Fig. 24). The marked negative curvature that previously prevailed has now given way to a more constant rate of responding. Some negative curvatures still exist, however, with the over-all rate falling from 0.45 response per second at the start of the session to slightly less than 0.2 response per second for the remainder of the session.

Number 67. The second subject, No. 67, again showed a greater sensitivity to the aversive effects of the time out by a progressive decline in the rate of responding as responses with larger interresponse time were punished. Records A–D of Fig. 23 show the development of the final performance with the punishment of responses spaced 0.33 second or more.

Record A contains the final performance of the variable-interval schedule without punishment. The normal variable-interval performance for this animal was characteristically lower than that for No. 97, and the characteristic negative acceleration was absent. The first two sessions (Records B and C), with punishment of responses spaced less than 0.75 second, show a progressive decline in the rate of responding, although instances of responses occurring within 0.75 second of each other still occurred, as the large number of time outs indicates. Record D contains the final performance 11 sessions after the criterion for punishment was changed to the punishment of responses spaced 0.33 second, or less. The over-all rate of responding increased somewhat, but the frequency of responses spaced 0.33 second apart, or less, was near zero, as evident from the fact that only one time out occurred.

The interresponse-time distributions of No. 67 for the prepunishment sessions (Sessions 1–7) show the generally prevailing low rate of this animal (Fig. 24). Responses spaced less than 0.33 second rarely occurred, and only 40% were spaced 1 second or less. Responses tended to occur more equally in all of the IRT categories than with No. 97. Responses

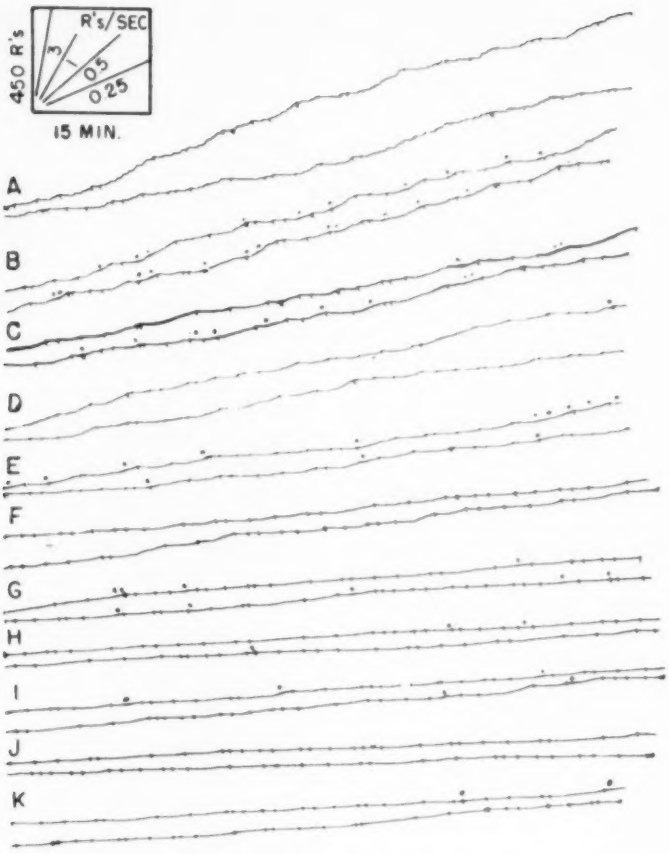

FIG. 23. Chimpanzee No. 67. Complete daily sessions showing performances with punishment of responses spaced less than 0.33, 1, 2, and 4 seconds.

A. Final variable-interval performance. No punishment.
B & C. Responses spaced less than 0.75 second are punished.
D. Responses spaced less than 0.33 second are punished.
E & F. Responses spaced less than 1 second are punished.
G, H, and I. Responses spaced less than 2 seconds are punished.
K. Responses spaced less than 4 seconds are punished.

spaced less than 1 second showed the largest decline in the frequency, when responses spaced less than 0.75 second were punished in Session 8. The remaining categories show progressively less effect of the punishment. During the remaining period of punishment of responses spaced less than 0.33 second, the 1-second IRT's fell to near zero; the 2- and 4-second IRT's showed a marked decline; but IRT's 6 to 18 seconds leveled off at a value slightly lower than the prepunishment base line.

Figure 25 is a daily plot, for No. 97, of

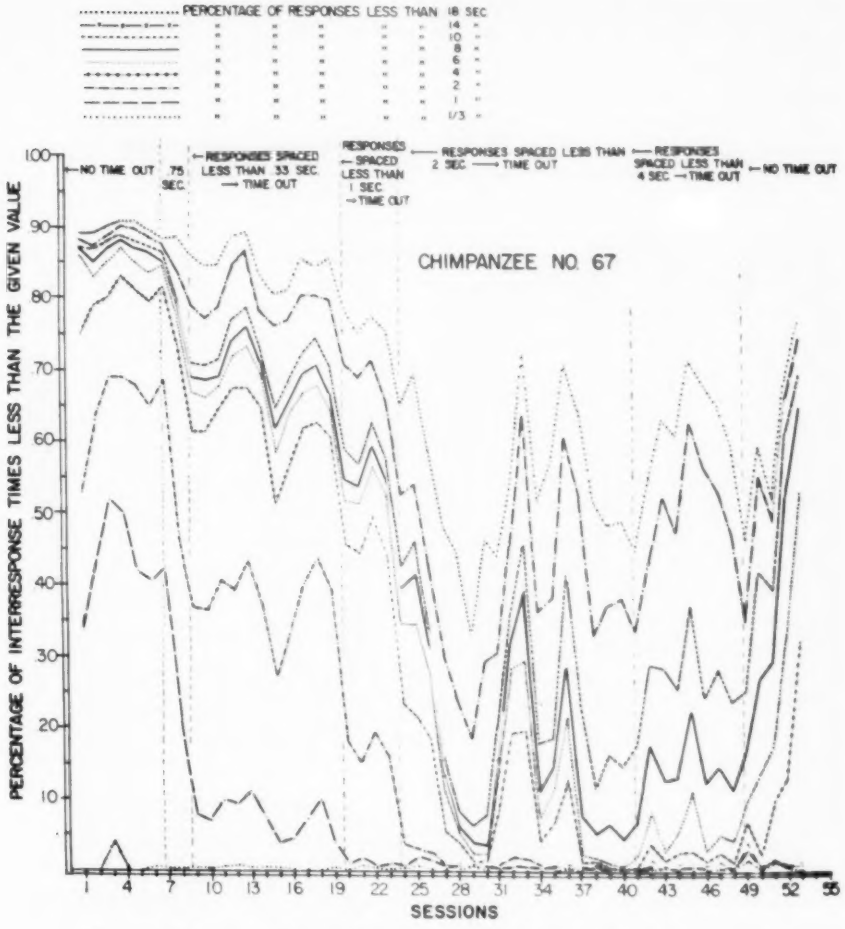

FIG. 24. Chimpanzee No. 67. Interresponse-time summary of the experiment.

the percentage of the total number of responses falling within each interresponse-time classification. The bottom curve contains the percentage of the responses in a given session which were spaced 0.33 second or less from a preceding response. The second curve contains the percentage of responses spaced 1 second, and so forth, as indicated by the figure legend. The top curve gives the percentage of responses spaced 18 seconds apart or less, and the difference between the top curve and 100% gives the percentage of responses in the daily session which were spaced 14 seconds or more apart.

The transition to the punishment of responses spaced 0.75 second or less occurs on the 10th session. Before this, 10% of the responses were spaced 0.33 second or less and most were spaced 1 second or

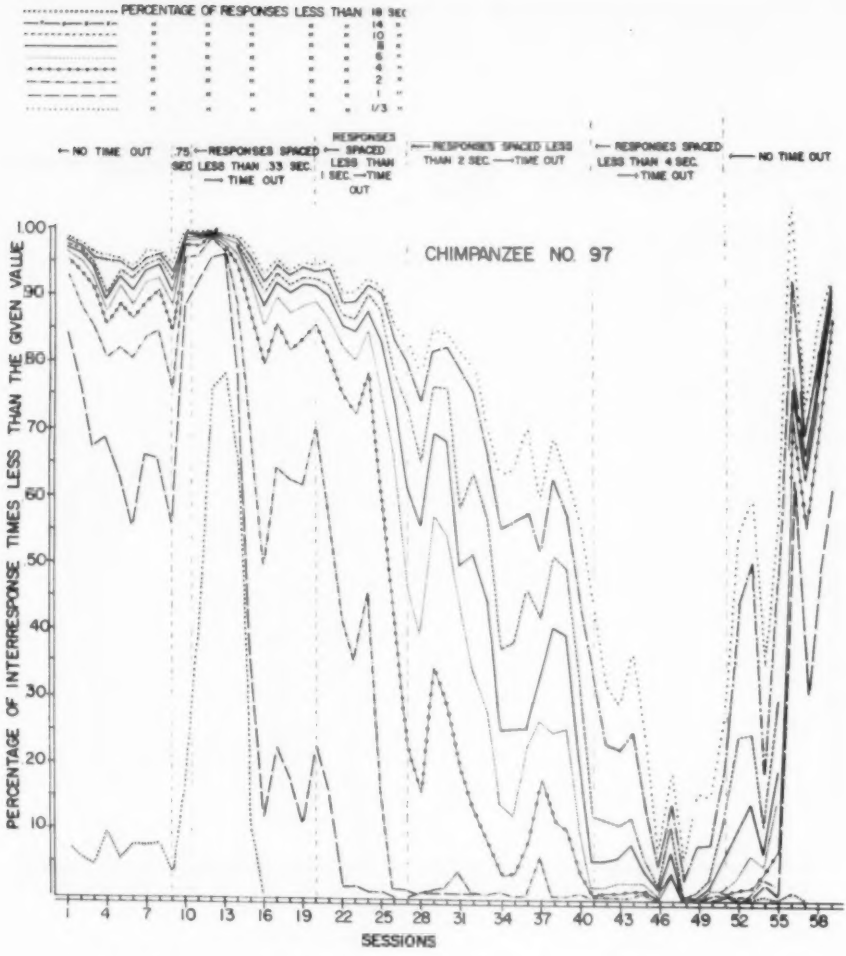
PERCENTAGE OF RESPONSES LESS THAN 18 SEC
" " " " " 14 "
" " " " " 10 "
" " " " " 8 "
" " " " " 6 "
" " " " " 4 "
" " " " " 2 "
" " " " " 1 "
" " " " " 1/3 "
← NO TIME OUT
.75 SEC ←RESPONSES SPACED LESS THAN .33 SEC. → TIME OUT
RESPONSES ← SPACED LESS THAN 1 SEC. →TIME OUT
←RESPONSES SPACED LESS THAN 2 SEC. →TIME OUT
← RESPONSES SPACED LESS THAN 4 SEC. →TIME OUT
→ NO TIME OUT
CHIMPANZEE NO. 97
PERCENTAGE OF INTERRESPONSE TIMES LESS THAN THE GIVEN VALUE
100
90
80
70
60
50
40
30
20
10
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58
SESSIONS

FIG. 25. Chimpanzee No. 97. Interresponse-time summary of the experiment.

less. Only 10% of the responses in this session are spaced 6 seconds apart or more. The first introduction of the punishment (Session 10, Fig. 20A) approximately triples the frequency of responses spaced 0.33 second, and almost 90% of the total responses of the session are spaced within 1 second of each other. In the second punishment session (Session 11, Fig. 20B) the rate of responding increases further, with almost 90% of the responses still spaced 1 second or less. When the punishment criterion was changed to 0.33 second (in Session 12, Fig. 20C), the rate increased further, with 75% of the total responses of the session spaced less than 0.33 second and 96% spaced less than 1 second. During the subsequent decline in the rate of responding from Session 14 to 19 (Fig. 21A–E and

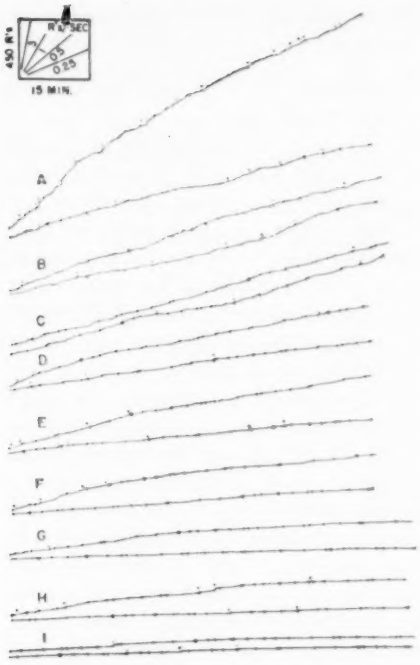

FIG. 26. Chimpanzee No. 97. Complete daily sessions showing performances with punishment of responses spaced less than 1, 2, and 4 seconds. A, B, C, and D, 1 second; E, F, and G, 2 seconds; H and I, 4 seconds.

Fig. 22), the percentage of responses spaced less than 0.33 second reached zero by the 16th session. Responses spaced more than 0.33 second also showed a decline in frequency, but the decline was progressively less marked for the lower rates. The frequencies of the various interresponse times remained stable during the remainder of the sessions.

Punishment of Responses Spaced Less Than 1 Second

Number 97. Figure 26 contains complete daily sessions for No. 97 in reduced form taken from 35 sessions during which the punishment criterion was increased to 1, 2, and 4 seconds.

Records A, B, C, and D represent the transition to the final performance during six consecutive sessions of punishment of 1-second IRT's. Record A, containing the first session, follows Fig. 22. The over-all rate began somewhat higher, and the number of time outs increased markedly over the value prevailing in the final performance with the smaller value. By the end of the session, however, the rate of responding fell to 0.15 response per second, compared with 0.25 response per second at the end of the previous session. In the second session (Record B) the negative curvature was greatly reduced, and the over-all rate of responding remained approximately 0.2 response per second. A large number of time outs still occurred. By the third session (Record C) the over-all rate of responding fell to approximately 0.15 response per second; and even though the over-all rate of responding was considerably below 1 response per second, instances of responses spaced 1 second or less still occurred occasionally, as the four time outs occurring during the session indicate. The final performance is shown in Record D, where the over-all rate of responding fell ever further. Responding at the start of the session began at approximately 0.15 response per second and fell to less than 0.5 response per second by the middle of the session.

Number 67. Number 67's performance is shown in Records E and F of Fig. 23, containing the sessions immediately following Record D. The punishment produces an almost immediate reduction in the over-all rate of responding, along with an increase in the number of time outs. In Record F, four sessions later, the rate of responding was extremely low during the first part of the session and higher during the latter part. No instance of a response spaced less than 1 second from a previous one occurred during the session.

Punishment of Responses Spaced Less than 2 Seconds

Number 97. Records E, F, and G of Fig. 26 contain the 1st, 6th, and 11th sessions for No. 97. Record E, which follows directly from the session in Record D, contains the first exposure to the new value. The rate of responding and the number of time outs do not change, because the previous punishment of responses spaced 1 second from a previous response depressed the rate of responding sufficiently so that very few pauses as short as two seconds occurred. By the end of Record E the new contingency produced the lowest rate yet observed. Six sessions later, in Record F, the over-all rate showed little change. Four time outs occurred during the initial high rate at the start of the session. By Record G, the 11th session, the over-all rate fell even further. The negatively accelerated portion at the start of the session was much reduced, and only one time out occurred.

Number 67. Record G of Fig. 23, the session following Record F, shows the first punishment of responses spaced less than two seconds for No. 67. There is a slight decrease in the rate during the latter part of the session and an increase in the frequency of time outs. The fourth session with this value (Record H) shows an even lower rate of responding, with fewer time outs; but after a total of 13 sessions with this value (Record I), the rate of responding increased to a value approximately the same as that prevailing when this value was first introduced in Record G.

Punishment of Responses Spaced Less than Four Seconds

Number 97. In Record H of Fig. 26, the session following Record G, the initial effect of the new contingency was a slight increase in the frequency of time outs and the over-all rate of responding during the first part of the session. The rate fell markedly by the end of the session, however. The lowest rate of responding on this value is shown in Record I, taken after 11 sessions. The high rate of responding that characterized the start of the session heretofore disappeared, and the performance became a constant rate throughout the session. Although the over-all rate of responding was already less than a response every four seconds, the punishment of the occasional four-second IRT's produced a further decrease in the over-all rate. The rate of responding began to increase in the next session, however, reaching the final performance shown in Fig. 27, 13 sessions later. The rate of responding was low at the start of the session; but it increased briefly early in the session in the region *a* to *d*, with responding during the time outs at *b* and *c*. For the remainder of the session the rate fell, reaching a value of approximately that obtained earlier in Fig. 26H.

Number 67. When No. 67's responses spaced less than 4 seconds apart were punished (Record J of Fig. 23), the first

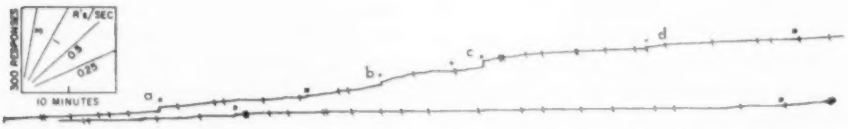

FIG. 27. Chimpanzee No. 97. Responses spaced less than 4 seconds are punished. Final performance.

effect was a decline in the rate of responding, followed by an increase in the rate five sessions later, in Record K. Note, however, that the rate of responding was already considerably below the critical value at which responses would be punished, and the increase in rate of responding occurring in Record K resulted in only two time outs for the entire session.

Interresponse-Time Records

Number 97. The punishment of responses spaced less than 1 second during the 20th to 26th sessions reduced the frequency of responses spaced less than 1 second to zero by the 26th session (Fig. 25). Responses spaced less than 2 seconds also declined markedly, but those spaced less than 4 seconds declined less. The remaining IRT classes also showed a decline in frequency, but only of the order of 5%, and reflected an over-all fall in rate rather than selective action of the punishment.

The punishment of responses spaced 2 seconds or less (Sessions 27–39) had little effect on the frequency of 2-second interresponse times, since this frequency was already near zero. As in the 1-second case, the effect of the punishment was selective, with IRT's nearest the punished one declining more than the longer IRT's. By the 39th session, over 30% of the responses were spaced *more* than 18 seconds from a previous response.

The punishment of responses spaced 4 seconds or less, beginning in Session 41, produced a further decline in the rate of responding, reaching the lowest value in Session 48. Almost 95% of the responses emitted in the session were spaced *more* than 18 seconds, even though only those responses spaced 4 seconds or less were punished. The decline in rate of responding occurred approximately uniformly in all the IRT classes. The increase in rate with further exposure to the punishment occurred in Sessions 48 to 54. The frequency of responses in the punished category ranged from zero to 0.04% and showed the least change. Responses spaced between 8 and 10 seconds showed the greatest change.

Number 67. In the case of No. 67 (Fig. 24) the punishment of responses spaced less than 1 second had little effect on these responses since the frequency was already near zero. The over-all rate of responding fell sharply, however, with no differential effect in any of the IRT categories under 18 seconds. The rapid decline in rate of responding continued as the criterion for punishment was increased to responses spaced 2 seconds; it reached the lowest value on the 29th session. Over 60% of the responses in this session were spaced more than 18 seconds, and 35% were spaced from 8 to 18 seconds.

The over-all rate of responding increased with further exposure to the punishment of 2-second IRT's and was reflected about equally in all of the IRT categories between 8 and 18 seconds. The increase in rate was not sustained, however, and the rate fell to a value somewhat higher than that prevailing previously in the vicinity of the 29th session.

The punishment of responses spaced 4 seconds or less, beginning on the 41st session, was followed by a temporary increase in the frequency of responses spaced 4 seconds or less, as well as a decrease in the frequency of responses spaced more than 14 seconds. With further exposure, responses spaced less than 10 seconds remained the same, along with an increase in the frequency of responses spaced *more* than 18 seconds.

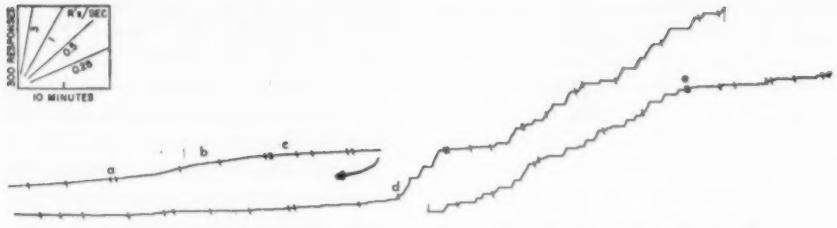

FIG. 28. Chimpanzee No. 97. Removal of the punishment. First session following Fig. 27.

Removal and Reinstatement of the Punishment Contingency

Number 97. On the session following the performance in Fig. 26, the punishment was discontinued and the procedure remained simply variable-interval reinforcement. Figure 28 shows the entire first session. The session began with the characteristic low rate until the region between *a* and *b*, when a slight increase occurred followed by a return to the prevailing low rate. After approximately 80 minutes, the over-all rate suddenly increased in the region *d* to a value almost comparable with that prevailing on this variable-interval schedule before the introduction of the punishment procedure. Local rates of responding reached 1.3 to 1.8 responses per second, and the grain of the record consisted of sustained bursts of responding separated by abrupt shifts to zero rates. Before the end of the session, however, beginning at *e*, the rate fell again. Following the performance shown in Fig. 28, the over-all rate of responding fell markedly, but subsequently increased, developing into a performance shown in Record A of Fig. 29, taken after 15 sessions without punishment. The highest over-all rate of responding was slightly lower than that which prevailed at the start of the session before the punishment procedure. The total amount of responding increased, however, because the high initial rate was sustained longer before it fell, as, for example, in the region *e*. The fine grain of the record shows frequent occurrences of smooth postively accelerated segments, terminating abruptly in a pause of several minutes, as at *a*, *b*, *c*, *d*, and *f*.

The interresponse-time analysis (see Fig. 25) shows residual effects of the previous punishment. The frequency of responses spaced less than 0.33 second

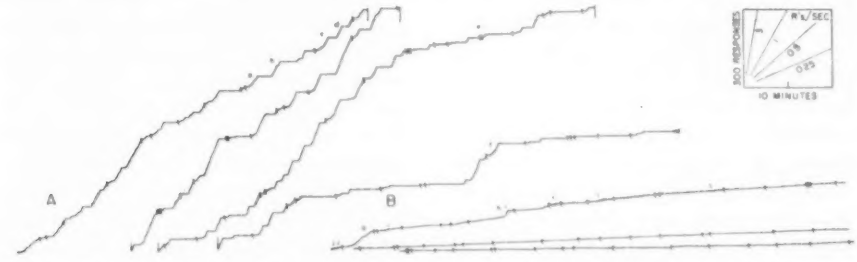

FIG. 29. Chimpanzee No. 97. Final performance without punishment (Record A) and the return to the punishment of responses spaced less than 4 seconds (Record B).

remained near zero, and responses spaced less than 1 second were less frequent than before the punishment. In the upper range of IRT's a substantial number of responses spaced more than 18 seconds occurred, compared with the number in the first nine sessions of the experiment. Most of the responses were spaced less than 2 seconds, or more than 12 seconds, compared with a more even distribution at the start of the experiment. The experiment was interrupted for five weeks between Sessions 58 and 59 with little effect.

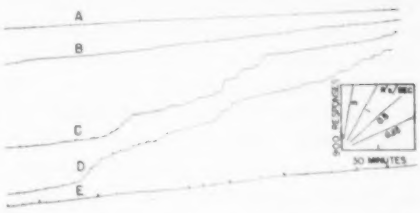

FIG. 30. Chimpanzee No. 67. Removal of the punishment and the subsequent reinstatement. A, B, C, and D. Ninth, tenth, fifteenth, and nineteenth sessions without punishment. E. Reinstatement of the punishment of responses spaced less than 4 seconds.

On the session following Fig. 29, the punishment procedure was reinstated. The result is shown in its entirety in Record B. Responses spaced less than 4 seconds were again followed by a time out. The rate of responding was low for the first few seconds of the session, similar to the start of the previous session (Record A). Time outs occurred during this period; and, after a brief increase in the rate for approximately 100 responses, the rate of responding fell to a low enough value for the rest of the session so that only six time outs occurred during the first part of the session. The rate became even lower for the latter part of the session, with no responding occurring rapidly enough to qualify for punishment. The rate of responding was high enough, however, so that reinforcements were still being received on schedule.

Number 67. The result of removing and reinstating the punishment procedure was similar for No. 97, except for a slower increase in the over-all rate of responding when the punishment of fast responding was first removed. The cumulative curves of Fig. 30 describe the transition to the variable-interval performances without time out and the subsequent return to punishment of responses spaced 4 seconds. Record A contains the ninth session after the removal of the punishment. The over-all rate of responding was essentially that prevailing under the previous punishment procedure, in spite of an increase in the frequency of responses spaced zero to 2 seconds.

The rate of responding increased somewhat in the next session, shown in Record B; and by the 15th session without punishment the over-all rate increased more substantially (Record C), reaching almost the final performance shown in Record D on the 19th session. The reinstatement of the punishment contingency at the start of Record E produced an immediate fall in rate to a value approximately the same as it was previously (see Record K, Fig. 23).

Discussion

Results of the experiment show that the selective punishment of fast responding will reduce the over-all rate of responding below that normally generated by the variable-interval schedule, and that the effect is reversible, with the approximate return of the original schedule performance when responses are no longer punished. The effect of the punishment is not entirely specific to those IRT's that are punished. The punish-

ment of a given rate reduces the rate of responding considerably beyond the value at which no responses would be punished, suggesting a spread of effect of the punishment similar to the effects of electric shock. This is illustrated by the initial effect of the 4-second punishment on No. 97, where the rate of responding fell considerably below a response every 4 seconds, so that the subsequent rate increase had little effect on the number of responses punished.

The effect of lowering the rate of responding by punishment of fast responses contrasts with the procedure of lowering the over-all rate of responding by withholding reinforcement until a low enough rate occurs (differential reinforcement of low rate); the over-all rate of responding remains slightly higher than the required rate, with the differential rate requirement being met by frequent instances of spaced responses. However, the tendency for the effect of the time out to generalize might disappear with longer exposure to a given value. This is suggested by the tendency for the punishment to initially depress the rate of responding below the value necessary to avoid punishment. The subsequent increase in rate occurred without any significant increase in the number of punished responses.

Limiting values probably exist beyond which the punishment contingency would be ineffective in reducing the rate of responding. The maximum value is probably a function of the length of the time out and the level of deprivation. Another limitation might be the ability of the animal to react differentially to the passage of time. In differential reinforcement of low rates by withholding reinforcement, for example, the animal's performance approximates the contingency better at higher rates. The performance of No. 67, during the punishment of responses spaced 4 seconds or less, suggests that 4 seconds is a limiting value for this animal under these conditions.

A low rate of responding was generated in this experiment by a progressive lowering of the rate. The contingencies in the situation suggest that a progressive program is most efficient; but it is not certain that initial prolonged exposure to an extreme value would not also be effective.

The large order of control by punishment with the time out from the same schedule of reinforcement used in Exp. I, II, and III gives further support to the findings of these experiments that the time out has two effects. The high rate in the pre–time-out stimulus occurs in spite of the general aversive properties of the time out demonstrated here and in Exp. IV.

Experiments with pigeons, using similar procedures, failed to confirm this result. The failure of the time out to suppress fast responding in the pigeon does not imply absence of aversive properties of the time out. In the face of other kinds of aversive control which have been established (Exp. III), the time out will probably suppress fast responding if the proper conditions are found. The difficulty is probably related to the effect of the time out in increasing the rate of responding, and the prepotency of this effect of the time out over the aversive properties.

Summary

Experiment I. A 30-second pre–time-out stimulus periodically preceded a 10-minute time out from a 3-minute variable-interval schedule of reinforcement. The rate of responding during the pre–time-out stimulus increased relative to

the over-all rate of responding. This increased rate was interpreted as a result of differential rate reinforcement by the selective effect of the time out on the spacing of reinforced responses.

Experiment II. The same variable-interval schedule of Exp. I was interrupted every minute by a 3-minute time out. The result was a large-order-of-magnitude rate increase compared with the uninterrupted performance. This function of the time out was analyzed in terms of its relation to the effect of the time out in Exp. I.

Experiment III. The aversive properties of the time out of Exp. I and II were emphasized by a procedure permitting the pre–time-out stimulus to terminate without a time out if the rate of responding were low enough toward the end of the pre–time-out stimulus. Under this procedure the rate during the pre–time-out stimulus fell to zero. Subsequent exposure to the same procedure produced a performance in which the rate of responding in the pre–time-out stimulus was negatively accelerated. Time outs did not occur because the rate of responding reached zero by the end of the pre-time-out stimulus.

Experiment IV. The generality of the aversive properties of the time out from the variable-interval schedule of Exp. I, II, and III was extended by generating avoidance behavior based on the postponement of the time out; the variable-interval schedule of food reinforcement of responses on one key was interrupted periodically by a time out unless a second key was pressed. Each press of the second key postponed the time out. Substantial levels of avoidance behavior were recorded at several values of length of postponement of the time out.

Experiment V. An examination of the properties of the time out used as punishment further established the generality of the aversive properties of the time out from the variable-interval schedule of Exp. I, II, III, and IV. The rate of responding on the variable-interval schedule was reduced when a time out selectively followed "fast responding." Responses of various interresponse times were punished with a resulting change in the rate of responding.

REFERENCES

1. Azrin, N. Some effects of two intermittent schedules of immediate and non-immediate punishment. *J. Psychol.*, 1956, **42**, 3–21.
2. Brady, J. V., & Hunt, H. F. An experimental approach to the analysis of emotional behavior. *J. Psychol.*, 1955, **40**, 313–324.
3. Dews, P. B. Studies on behavior. I. Differential sensitivity to pentobarbital of pecking performance in pigeons depending on the schedule of reward. *J. Pharmacol.*, 1955, **113**, 9.
4. Dinsmoor, J. A. Punishment: I. The avoidance hypothesis. *Psychol. Rev.*, 1954, **61**, 34–46.
5. Estes, W. K., & Skinner, B. F. Some quantitative properties of anxiety. *J. exp. Psychol.*, 1941, **29**, 390–400.
6. Ferster, C. B. The use of the free operant in the analysis of behavior. *Psychol. Bull.*, 1953, **50**, 263–274.
7. Ferster, C. B., & Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
8. Herrnstein, R. J. Behavioral consequence of removal of a discriminative stimulus associated with variable-interval reinforcement. Unpublished doctoral thesis, Harvard Univer., 1955.
9. Herrnstein, R. J., & Morse, W. H. Escape behavior maintained by the removal of a stimulus correlated with an intermittent schedule of food reinforcement. Paper read at Eastern Psychol. Assn., Atlantic City, March, 1956.
10. Hull, C. L. *Principles of behavior*. New York: Appleton-Century-Crofts, 1943.
11. Miller, N. E. Learnable drives and rewards. In S. S. Stevens (Ed.), *Handbook of experimental psychology*. New York: Wiley, 1951.

12. MORSE, W. H. An analysis of responding in the presence of a stimulus correlated with periods of nonreinforcement. Uupublished doctoral thesis, Harvard Univer., 1955.
13. MORSE, W. H., & HERRNSTEIN, R. J. The maintenance of avoidance behavior using the removal of a conditioned positive reinforcer as the aversive stimulus. *Amer. Psychologist*, 1956, **11**, 430. (Abstract)
14. SCHOENFELD, W. N. An experimental approach to anxiety, escape, and avoidance behavior. In P. H. Hoch & J. Zubin (Eds.), *Anxiety*. New York: Grune and Stratton, 1950. Pp. 70-99.
15. SIDMAN, M. Two temporal parameters of the maintenance of avoidance behavior by the white rat. *J. comp. physiol. Psychol.*, 1953, **46**, 253–261.
16. SIDMAN, M. Technique for assessing the effects of drugs on timing behavior. *Science*, 1955, **122**, 925.
17. SKINNER, B. F. Superstition in the pigeon. *J. exp. Psychol.*, 1948, **38**, 168–172.
18. SKINNER, B. F. How to teach animals. *Sci. Amer.*, 1951, **185**(6), 26-29.
19. WILSON, M. P., & KELLER, F. S. On the selective reinforcement of spaced responding. *J. comp. physiol. Psychol.*, 1953, **46**, 190–193.

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